Meeting scientists
Impacts on visitors to the Natural History Museum, London

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Meeting scientists:

Impacts on visitors to the Natural History Museum, London

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Abstract

This thesis focuses on how face-to-face interactions with scientists, during a visit to a natural history museum, can have an impact on how visitors conceptualise and identify with researchers. The study draws together the literature on attitudes to science and perceptions of scientists, whilst also focusing on identity development in individuals, using the concept of interest to study impacts on engagement.

The study adopted a qualitative approach primarily involving interviews with 81 adult visitors and 38 A-level students (aged 16-18) meeting scientists in museum-based discussion events. Participants were interviewed before, immediately after, and two months after meeting scientists to explore longer-term impacts.

Meeting scientists had an impact on visitors' and students' identification *of* and *with* scientists. Visitors and students held conceptual ecologies around perceptions of scientists, drawing on multiple ideas about scientists concurrently. Visitors and students identified more closely with scientists following their interaction, recognising common experiences, and visitors also developed a lasting interest in scientists and their career histories.

I propose the notion of scientists as 'everyday experts': knowledgeable individuals with clear areas of expertise who are also approachable and accessible. A 'midway' approach to public engagement is recommended to facilitate the presentation of scientists as 'everyday experts'; an intermediate approach between a deficit, one-way communication and a two-way dialogue between scientists and the public.

Meeting scientists is shown to bring 'added value' in terms of increasing scientific literacy: perceptions of scientists became more positive and less stereotypical and participants learned about particular areas of science as a result of the session. Meeting scientists was also shown to provide 'added value' in promoting science engagement: visitors reported continued engagement with science in the delayed post-session interviews two months after the visit. I discuss the implications of my findings for research and practice, with the aim of further understanding how to develop scientific literacy and engagement.

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Chapter 1: Introduction

1.1 Background

This chapter introduces the research which explores the impacts of meeting scientists on visitors to the Natural History Museum, London[1]. I begin with a discussion of the role of researcher-practitioners in education and museum settings. Next, I give a synopsis of recent developments in the fields in which this research is situated: public engagement with science, and museums and out-of-school learning. The overarching aim for this research is then introduced: to contribute to knowledge on how scientific literacy and engagement with science can be encouraged within the adult population. The chapter ends with a summary of the research questions and, finally, an overview of the thesis structure.

1.1.1 Links between research and practice in out-of-school science learning

There have been many examples of calls for closer ties between researchers and practitioners in the science education and museum learning fields so that research more accurately reflects the issues and problems practitioners face and so that those working in the educational settings utilise and implement research to its full potential (for example Bartels, Semper, & Bevan, 2010; King & DeWitt, 2013). One example of such a call comes from the recent review into science learning outside the classroom in the UK commissioned by the Wellcome Trust. The review suggested that there is a lack of synergy in what it termed the 'informal science learning' sector between the research literature and practice, and recommended that a closer link between research and practice could improve professional development, identify gaps in theory and encourage more practice-oriented research (Mattherson & Holman, 2012).

The current research has been undertaken as part of a collaborative PhD studentship – a partnership between King's College London and the Natural History Museum, London (hereafter referred to as 'the Museum') – which has meant that the association between research and practice has been particularly strong and influences from both communities are present in this work.

[1] The Natural History Museum chose to not remain anonymous in this study.

Rounds (2007) argues that the consumption of research by practitioner communities needs to keep pace with the production of the research, otherwise an ever-widening distance or lag between research and practice will develop. The need for research to more effectively influence practice is not unique to science education but has been discussed in education more widely, recently in terms of encouraging 'Knowledge Mobilization' (Levin, 2013). Levin stresses that the process of knowledge mobilization is interactive, social and gradual, and takes place as a result of interaction between three domains – the production of research, the use of research, and the mediation between the two. In my role as a researcher situated within a museum, I aim to bridge the gap between research and practice through my work, acting as the mediator to which Levin refers.

Researcher-practitioners in the field of education are individuals who are working in museums and schools and conducting research on their own practice and/or that of their colleagues (Carter, Castle, & Soren, 2011). An advantage of being a researcher-practitioner is a familiarity with the research focus and related issues. This close involvement with the research focus can, however, also be problematic, especially when aiming to maintain a neutral and objective perspective on the object of study. I have worked in close proximity to the practices that I have been studying at the Natural History Museum, London for three years. I, therefore, faced similar dilemmas, opportunities and issues as researcher-practitioners in other educational settings and this positioning will have influenced my research throughout.

1.1.2 Background to this research

My interests in this research stem from my experiences as a science student and, more broadly, as someone my friends would call a 'science person'. I studied biology at university, having always found it a fascinating subject. The more that I spoke to people outside my course about biology, the more interested I became in their reactions to studying science beyond school. These reactions included 'biology is so hard', 'I just never *got* science' and 'why would you carry on with science after school?' The more I learned about biology, the more I could see its relevance and importance, whereas my friends and family who were not studying science, found it difficult, irrelevant and inaccessibly academic. What was I seeing that they were not? What made science so off-putting and why was I not deterred? What made me a 'science person' and others not? And why did I see science as more relevant and closer to everyday life than did others?

While completing my MSc in Science Communication, I worked in a science centre in the South West of England, coordinating and developing programmes, events and activities for visitors. I was intrigued that visitors of all ages seemed to be enjoying science and engaged with the activities within the science centre. In particular, I noted their positive and excited reactions to the scientists involved in the 'Meet-the-expert' programme. As such, I became curious as to the role that places such as museums and science centres could play in engaging people with science, sparking interests, portraying the importance and relevance of science and providing opportunities for people to meet scientific experts. Thus I was led to a PhD researching the impacts of public engagement with scientists.

1.2 Thesis setting

This research is situated within the area of science learning and public engagement with science in particular. It draws on work carried out in out-of-school science learning environments, museums and science centres. In this thesis I use the term out-of-school science learning as opposed to informal learning as the former term more accurately reflects the fact that there are not different types of learning *per se*, but different learning environments. See section 2.2.2 for a more detailed discussion of this argument. Research has identified many potential impacts of learning in out-of-school contexts – this thesis focuses on an area as yet rarely studied, increasing scientific literacy and engagement with science as a result of meeting scientists in public engagement events hosted by a museum.

The wider fields of public engagement with science and learning in out-of-school settings have influenced this work, along with ideas on scientific literacy and engagement. The experience of meeting scientists in museum settings represents the convergence of the fields of science communication and museum education, and this research draws from work in both fields. Despite their different foci and theoretical backgrounds, the application of both fields to this thesis is appropriate and useful. The fields share common aims and rationale around the education of publics about science and developing positive public attitudes, research has used similar methods including interviews and observations, and analyses have focused both on individual and population levels. Ellenbogen (2013) discusses the convergence of the fields of science communication and learning outside the classroom, pointing out that both aim for similar impacts on their audiences and suggesting that considering them simultaneously may lead them to be more effective than the sum of their parts. Recent developments in relevant research, policy and practice within these two fields are introduced below; a more detailed discussion on relevant findings and theories is developed in Chapters 2 and 3.

1.2.1 Public engagement with science

The definition of public engagement has changed somewhat since it first became widely used following the UK House of Lords Select Committee on Science and Technology report, *Science and Society* (2000). Public engagement was originally regarded as scientists consulting with various public bodies on the direction of their research, however it is now used more broadly to describe any contact between the public and scientists (Dillon, 2011). Although the types of activity covered by the term 'public engagement with science' have diversified, the majority of those in the field would agree that public engagement requires some element of two-way communication, as opposed to a didactic one-way transmission of information. For example, a Centre for the Advancement of Informal Science Education (CAISE) Inquiry Group Report defines public engagement as 'A multidirectional dialogue among people that allows all the participants to learn' (McCallie *et al.*, 2009, p. 12). Davies (2013) comments on the issues of using such a broad definition of public engagement – to include any two-way communication between parties – arguing that it leads to difficulty in comparing and studying the impacts of engagement efforts. Davies studied public engagement events in the Dana Centre, London, in terms of power relations between the scientist and the non-expert audience, exploring whether the public engagement activities were truly dialogic. Davies's work will be returned to later in this thesis when investigating public engagement events at the Natural History Museum, London.

1.2.2 Learning science in out-of-school contexts

Science learning environments have faced new dilemmas in recent times with the development of new technologies, access to information and renegotiating their place within society and culture. Science centres and museums can create memorable learning experiences: they have large and iconic objects; often impressive architecture and spaces; and, can create immersive learning experiences and social interactions amongst learners (Ucko, 2013). The most relevant of Ucko's (2013) suggested unique assets of science centres and museums for my research is their authenticity: museums have real and authentic objects, they are sources of knowledge and expertise, and offer chances to meet a real expert. Museums and science centres, however, must compete with an increasing and diversifying number of other learning activities and events to engage audiences. To maintain their positions as key institutions for learning and to continue to attract visitors, museums and science centres must utilise their unique attributes such as authentic objects and the opportunity to interact with experts.

Attempts have been made to review the field of learning science outside the classroom and develop more strategic learning research agendas. For example, in the UK the Wellcome Trust commissioned two reviews into 'informal science learning', published in November 2012 (Falk *et al.*, 2012; Lloyd, Neilson, King, & Dyball, 2012). In the US, the Smithsonian's National Museum of Natural History organised a conference to establish a research agenda for 'Twenty-first Century Learning in Natural History Settings', gathering colleagues from institutions around the world to discuss important issues requiring research. The themes that emerged from this conference as priorities for a research agenda included: critical content; diversifying audiences and extending outreach; facilitation and mediation of learning across different platforms; connecting learning and organisational change; authenticity and the role of collections and learning from objects and data (Watson & Werb, 2013).

The Smithsonian conference sparked a number of conversations within the natural history museum community about the implications for individual institutions and future practice. Two of these conversations were published alongside a summary of the conference discussions in a recent issue of *Curator*. Researchers from the Carnegie Museum of Natural History reflected on the impact of the conference on their own work, including the realisation that museums were in fact increasingly visitor-centric and relevant in society, due to concerns about biodiversity, conservation and periods of rapid change for the environment and the planet (Steiner & Crowley, 2013). The resulting aim for the Carnegie Museum was to generate new knowledge about learning and disseminate the museum's research internationally.

In their paper, Steiner and Crowley also stress that they aim to establish partnerships with other institutions in order to build a stronger learning ecology in the museum's surrounding area. These ideas fit with my aims for the current research: to understand how increased interest, scientific literacy and engagement with science can be encouraged, whilst considering museums as one of many aspects of a network of lifelong learning events. I speak about this perspective in more detail in Chapter 2.

Authors from the Natural History Museum in London also published reflections following the Smithsonian conference (Irwin, Pegram, & Gay, 2013). As a result of those discussions Irwin *et al.* aimed to identify a new strategic direction for research and evaluation at the Museum, ‘Moving from an inward-looking approach regarding research and evaluation that only serves the Museum’s business needs, to understanding learning in natural history museums more widely’ (Irwin *et al.*, 2013, p. 274). My PhD research goes some way to broadening the work that is carried out in the research and evaluation team at the Museum, developing ideas and conclusions which not only apply to the Natural History Museum, London, but also other science learning institutions more widely.

Another recent and influential review into learning in informal environments was commissioned by the US National Science Foundation, reported on six main strands through which institutions contribute to science learning outside the classroom (Bell, Lewenstein, Shouse, & Feder, 2009). The strands included affective as well as cognitive outcomes, inquiry skills, understanding of the nature of science and the development of science identities and interest. A response to this report, published a year later, discussed the implications for practice (Shouse, Lewenstein, Feder, & Bell, 2010). Shouse *et al.* (2010) pose three recommendations for conducting research and evaluation following the report:

- Staying open to a broad range of possible outcomes from the experience;
- Taking into account the norms and nature of the museum experience for participants;
- Making sure what is measured is true to learners’ experience and educational intent (Shouse *et al.*, 2010, p. 148).

These three recommendations are principles which I have also considered and adopted in my own work and can be seen reflected in the methods discussed in Chapter 4 ‘Methods and Methodology’.

1.2.3 Scientific literacy and engagement with science

The aim of this research is to add to the body of knowledge about how best to encourage increased scientific literacy and engagement with science amongst the general population. By ‘general population’ I include both those who *do not* work in science and have not studied science, along with those who *do* work or study in science, as scientists may be experts in their one area of specialism in science, but may not necessarily be interested or engaged in others.

i) Scientific literacy

Scientific literacy is defined broadly as being informed by science and familiar with it, although despite the term existing for at least 60 years, a precise definition has not emerged (DeBoer, 2000). There are, however, several terms that are recognised as part of scientific literacy.

Historically, the term scientific literacy has been associated with a deficit model of communication, experts ‘fill up’ non-experts with their information, and non-experts absorb this information in a passive way. When citizens are adequately ‘full’ of information, to a level decided by experts, they could be described as scientifically literate. More recently, scientific literacy has been described in a broader way, as the overarching aim of some educational reforms, for example the Twenty-First Century Science project on curriculum reforms for 15-16 year-olds in the UK (Millar, 2006).

To be scientifically literate, in this research, I imply that people are confident and aware enough around science that they feel comfortable to engage with new scientific information, issues and questions, and understand the process and nature of scientific research so that they can interrogate and interpret information and make informed decisions. Scientifically literate individuals will be able to ask questions of science and access science information. DeBoer describes a similar aim and definition of scientific literacy:

> *Ultimately what we want is a public that finds science interesting and important, who can apply science to their own lives, and who can take part in the conversations regarding science that take place in society*. (DeBoer, 2000, p. 598)

Roberts made a distinction between two types of scientific literacy, identifying two ‘visions’ (Roberts, 2007). Vision I relates to looking inwards at science, at its products and processes, in relation to preparing future scientists. Vision II refers to an outward facing scientific literacy – preparing students as citizens to engage with science in their everyday lives, particularly in terms of decision-making around socio-scientific issues (Roberts, 2007). The current research focuses on Robert’s Vision II, as promoting the development of active and informed citizens in relation to science is a broader issue and relevant to a wider section of the public. That said, aspects of Vision I are also important, particularly in relation to the A-level students involved in the research.

A definition of scientific literacy as preparing future citizens to deal with scientific issues relevant to their own lives addresses some of the criticisms posed by Shamos (1995) of the use of the term scientific literacy and an over-focus on scientific knowledge. Shamos advocates for science awareness, including awareness of how scientific research works, feeling comfortable with science and knowing what to expect from science. Whereas the more traditional definition of scientific literacy assumed that once citizens were scientifically literate they would appreciate and value science more, the adapted definition I use here reflects aspirations to nurture confident and engaged citizens who can form their own ideas and attitudes towards science. These attitudes, whether positive or negative, are based on accurate information and realistic perceptions of science and scientists. In the same way that literate means to be able to read and write, scientific literacy can signify the ability to digest, interpret and use scientific information.

Scientific literacy is important for modern society, as argued by Irwin and Wynne (1996) – a higher level of scientific literacy amongst the public will arguably contribute to innovation, more informed public decision-making, a better understanding of risk and uncertainty, and awareness of how science can aid living and everyday life (Hines, Mervis, McCartney, & Wible, 2013). Scientific literacy is increasingly important as science and technology research fields are expanding and developing, creating new issues and dilemmas and influencing our personal decisions. For example, an informed individual would be able to make decisions about their personal consumption of energy based on scientific information, including why they might want to conserve energy in terms of economic and environmental implications, and whether they would want to use renewable energy sources such as solar panelling on their house or buy an electric car.

In order to feel confident and able to not only digest and process science information, but also to be motivated to find out more about scientific topics of relevance, citizens need to be scientifically literate and engaged. In this work, scientific literacy and engagement may be thought of as on a spectrum; scientific literacy involves being familiar with the process and nature of science, and being able to use scientific information, whereas engagement is a more active involvement in science, building on scientific literacy, taking part in activities relating to science as part of hobbies and interests. For example, a scientifically literate and engaged citizen might assess the reliability of information they hear on a news documentary based on a single case study, actively seeking further information to support or challenge this in order to make an informed decision on the topic.

ii) Engagement with science

There is a further aim to this research, beyond scientific literacy, and that is for increased engagement with science. Engagement goes beyond the ability to digest, interpret and use scientific information and is about interest in finding out more and participating further in science. Science engagement takes a huge diversity of forms and might include watching science programmes, visiting museums, reading books or articles on science, or attending lectures and courses. Engagement with science may lead to people taking a more active part in their own science learning outside of school, encountering more information and developments in science, and experiencing more images and representations of scientists. Increased engagement may also result in people having opportunities to develop their own attitudes, perceptions and identities in relation to science, seeing how science fits with their own lives and how it relates to the kind of person they see themselves as being. Such development of perceptions and identities in relation to science may be described as developing personal awareness of science and technology (Stocklmayer & Gilbert, 2002).

Engagement, as defined by Hampden-Thompson and Bennett (2013), includes cognitive engagement, emotional engagement and behavioural engagement (following work from Finn, 1989; Fredricks, Blumenfeld, & Paris, 2004). Cognitive engagement involves a motivation to learn and master a topic, developing knowledge and skills to do with the subject. Emotional engagement refers to identification, interest, enjoyment and other affective reactions to the subject. Behavioural engagement relates to participation and involvement in relevant activities to the subject. The current work uses aspects of all three strands of engagement.

Research into attitudes towards science and scientists and the impacts of interactions between scientists and non-scientists has predominantly focused on encouraging more students to pursue careers in science (for a review see Osborne, Simon, & Collins, 2003). Whilst it is an important issue to maintain interest amongst young people for science careers, it is not the main focus of my research. It has been debated as to whether the UK really needs more scientists and what percentage of students *should* be encouraged to pursue science studies and careers. Some researchers argue that it is unethical to put such emphasis on encouraging students into science when there are so few jobs for them once they have graduated (Osborne & Dillon, 2008; Smith, 2010; Smith & Gorard, 2011). I believe that a more pressing issue than encouraging more students to become scientists, and one which would affect a broader section of the population, is increasing engagement and awareness of science in a way that leads to citizens being empowered and motivated to make informed decisions about science when it affects their lives. In some cases, students may then progress from this literacy and engagement to develop an enhanced science identity in which they consider pursuing a career in science.

I would argue that increasing scientific literacy and engagement with science more broadly will maintain options for all students to enter science study and careers. Increased literacy and engagement may make it more likely that students will see science as something which is interesting and relevant. Presenting more realistic images of scientists may also contradict the belief that only students from certain backgrounds or with certain personalities are able to go into science. Furthermore, targeting a broader audience to influence attitudes and perceptions of science may be likely to lead to parents and teachers, or adults who may become parents or teachers in the future, holding more positive and realistic ideas about science and science careers. These adults may, therefore, be more likely to encourage children or students towards this field. Parents and teachers have been shown to have a significant influence on career decisions, and so increasing scientific literacy and engagement with science amongst adults is valuable (Archer *et al.*, 2012b; Archer, DeWitt, Osborne*, et al.*, 2013a). The aims of this study, therefore, are at a general and broad-reaching level, aiming to increase scientific literacy and engagement within the whole population, which in turn, and incidentally rather than deliberately, may lead to increased numbers taking science-related career paths. This study aims to encourage the development of a general population informed and interested in science.

On the whole, public attitudes to science have become more positive in recent years; at present the UK is at a stage where science is broadly accepted by non-scientists, there is a general level of awareness and often an appreciation that science is important in our society (Bennett & Hogarth, 2009; Ipsos MORI, 2011; Jenkins & Nelson, 2005). Although science is widely seen as important and beneficial, science is less frequently seen as personally relevant or interesting (Jenkins & Nelson, 2005). Is this 'passive acceptance' of science enough? Should those working in the science engagement sector be content that people do not feel threatened by science and are, on the whole, accepting of it? Or should the aim be for more than passivity? Should the science museum sector, in fact, want people to feel engaged and excited by science, to see personal relevance, to make links and associations, and to develop a personal interest and, therefore, a stake in science, holding it to account and questioning it?

A move towards a more engaged, interested and active citizenship accords with developments in the science engagement field within the last 15 years (UK House of Lords Select Committee on Science and Technology, 2000; Wilsdon & Willis, 2004) which have called for a two-way public engagement with science model of communication rather than a deficit one-way transmission model. Under this public engagement model, various publics are seen as being more involved in the scientific process, rather than being passive recipients of information. However, the initial call for public engagement with science rather than public understanding of science was made more than a decade ago. Has this outcome been achieved, and if not, why not? There seems to be a general trend towards attitudes to science becoming more positive, and trust in scientists in particular has increased, although trust in private industry and government scientists remains lower than for those working in other institutions (Ipsos MORI, 2011; 2014). As I discussed above, for citizens to really want, and be able, to engage in a deeper way, science has to be seen as something which is relevant, interesting and personally important.

It has been suggested that for non-scientists to engage with policy and science further, the public image of scientists must be addressed (Losh, 2010). In particular, it has been argued that students must have a realistic appreciation of the work scientists do and hold positive, non-stereotypical images of scientists (Schibeci, 2006). The current research, therefore, suggests that one way in which science learning experiences outside the classroom could encourage scientific literacy and engagement, would be to focus on the images of scientists that people hold and how those might be influenced through interactions with actual scientists so that the images are more, realistic, relevant and interesting.

1.2.4 The roles of scientists in public engagement

As the diversity of public engagement activities widens, an increased pressure is placed on scientists to engage with the public. The growing pressure on scientists to communicate about their work is evident in the increasing prominence of public engagement activities in funding requirements and direction from senior staff members. For example the 'Science Strategy' at the Natural History Museum for 2013-2017 sets out science engagement as one of three focal areas for the Science department, with the target of delivering one million face-to-face interactions between scientists and public audiences in the next five years (Natural History Museum, 2013c). New facilities and exhibitions in the Darwin Centre at the Museum also focus on visitor interactions with scientists and involve science staff in the delivery of education programmes.

With more public engagement activities encouraged and developed, there is a parallel call for more research on the impact of public engagement activities (Dillon, 2011). A new journal dedicated to this research was launched in 2011; the *International Journal of Science Education Part B – Science Communication and Public Engagement*. Research into the impacts of public engagement with science and scientists in museum settings is, therefore, timely.

1.3 Thesis overview

1.3.1 Research aims and questions

This PhD research addresses the following research questions, with the guiding aim of contributing to knowledge on increasing scientific literacy and engagement with science. The overarching research question is ‘What are the impacts of meeting scientists on visitors to the Natural History Museum, London, and to what extent do these impacts last beyond the immediate experience?’ This question is then subdivided into two contributing elements:

1. How does meeting a scientist impact visitors’ identification *of* scientists?
2. How does meeting a scientist impact visitors’ identification *with* scientists?

The first chapters in this thesis include a discussion of the development of the research questions. Briefly, the overall focus was selected as a result of a modified Delphi study, consulting Museum staff on the topics they felt were important to be researched (Seakins & Dillon, 2013). The sub-questions were then refined as a result of a review of the academic literature. These questions thus reflect current and relevant concerns from the field and are grounded in the theoretical perspectives outlined in the following chapters.

Evaluation work has been carried out in the Natural History Museum looking at programmes and exhibitions, but comparatively little academic research has been undertaken. Evaluation makes a value judgement on the success or effectiveness of an initiative within a specific context, whereas research makes a contribution to knowledge about an initiative or its impacts, applicable outside the specific context. Hein (1998) discusses the differences between evaluation and research in a museum context, describing how evaluation aims to solve practical problems which are specific in nature, whereas research adds to the knowledge about a situation or practice. This research study, therefore, builds on the existing evaluation conducted in the Natural History Museum and research literature from elsewhere, to explore the impacts of meeting scientists applicable and relevant to other public engagement contexts.

There are a number of terms used in the research questions that would be useful to clarify at this point. The term ‘scientist’ refers to a member of the scientific staff at the Museum: this might be a scientific researcher or a curator, somebody working in the collections or in technical areas of the Museum, or those conducting original research themselves. A scientist may be at any level of their career, from PhD student to established researcher.

Advertisements and information in the Museum use the same definition – scientists are those members of staff from the Science group – and as this is the communication the visitors will encounter it makes sense to follow the same definition.

The next point to address, then, is what counts as 'science'? Studies into science attitudes have tended to focus on one particular field or subject area at a time, for example biology in laboratory workshops, or electricity and magnetism in science exhibits (Anderson, Lucas, Ginns, & Dierking, 2000). Cumulatively these studies then form the literature on attitudes to science. In this thesis I will define science broadly. When reviewing previous work I include literature from all STEM (science, technology, engineering and mathematics) subject areas. In terms of the data collected and presented from this study, however, the definition of science will be restricted to natural sciences: the areas of scientific research carried out at the Natural History Museum, including entomology, zoology, botany, mineralogy and palaeontology.

The 'visitors' mentioned in these research questions might be adults visiting the Museum, or A-level students attending A-level biology 'Behind-the-Scenes' days with their class. More detail on why these particular groups of visitors were chosen as the subjects of detailed study is given in section 4.3.2. 'Meeting a scientist' refers to interactions between members of the visiting public and scientists during a 'Nature Live' event. Nature Live events are half-hour discussion events with a Museum scientist, facilitated by a host (a member of the Museum staff from the Public Engagement Group), in which the scientist speaks about their research, showing pictures, videos, specimens and equipment, and the audience is invited to participate through questions, voting and, sometimes, games. A-level students meet scientists during similar Nature Live sessions and through behind-the-scenes tours, where scientists show students their working areas, laboratories or collections spaces, often showing specimens and scientific equipment and speaking about their research and own scientific careers.

'Impact' is conceptualised deliberately broadly here, in order to explore the widest possible results the experiences may have on the individuals meeting scientists. Impacts may include changing attitudes towards science, science careers and the Museum itself, and developing or diminishing levels of interest in science. Sessions may impact upon visitors in terms of influencing perceptions of scientists, and/or awareness of the nature of science. Impact might involve cognitive learning about specific science content, science processes and scientific careers. Individuals may develop confidence and skills relating to science work; identify connections to science and links to the scientists; and, change their ideas of self-image in science about whether or not the individual sees themselves as a 'science person'. Two areas where there may be potential impact, in particular, are addressed in the sub-questions, ‘identification *of*’ and ‘identification *with*’ scientists.

The overarching research question for this study includes a question about the longevity of impacts of meeting scientists. Longevity of any impacts identified is important to assess if the aim of the research is to understand how an interaction with a scientist might contribute to scientific literacy and engagement. Learning takes time, and so only studying visitors immediately following an experience may mean some impacts are missed (Rennie & Johnston, 2004). Also, other impacts may be short-lived and may not last beyond the immediate experience, as seen in studies into attitude change following a visit to a space centre (Jarvis & Pell, 2005). Therefore, research which fails to study the longer-term impacts of an experience, after time has elapsed, may miss some impacts and represent others which last only instantaneously.

‘Identification *of*’ scientists refers to changes in perceptions of scientists, images of those working in science and ideas about who might or might not have a job in science. This idea is related to, but is not exclusively about, traditional stereotypical images of scientists. For example, meeting a scientist may change, or confirm, previously held stereotypical ideas. This area of impact also relates to the awareness and appreciation of science jobs and careers, understanding the diversity of science careers and the variety in the scientific fields in which people work.

‘Identifying *with*’ something involves seeing similarities between it and one’s life or experiences. Identification *with* scientists therefore relates to the personal connections people see with science and scientists, for example, seeing science as relevant and interesting, and identifying similarities between themselves and the scientists they meet, so that they might identify with them on a personal level (Barton & Tan, 2009). The process of identifying with another person has also been studied in relation to viewers identifying with figures in the media (Cohen, 2001; Hoffner, 1996; Hoffner & Buchanan, 2005). The current research will aim to explore how identification with scientists is impacted as a result of meeting scientists face-to-face, as opposed to virtually or through another form or media.

The two areas of identification *of* and *with* scientists were chosen as the focus of this study as they draw together the existing literature on attitudes to science and perceptions of scientists, whilst also taking a more recent perspective of looking at identity development in individuals. These two focus areas of impacts (identification *of* and *with* scientists) are relevant for increasing scientific literacy and engagement with science, in terms of broadening perceptions of scientists and their work, and increasing the connections individuals feel with science, including being relevant and interesting to their own lives. By understanding how people view science and how they connect to science in relation to their everyday lives, we can better understand how to encourage science engagement and utilise resources for engagement in the most efficient way (Zimmerman & Bell, 2012). Examining these two areas of perceptions and connections simultaneously in a museum setting is one way in which this thesis adds new knowledge to the field.

1.3.2 Thesis structure

This thesis discusses the research undertaken in order to address the research questions, including the development of the questions, the identification of relevant existing work, the methods adopted, the research findings, a discussion of the conclusions reached and the implications of the work.

Chapter 2 describes the context of the research in terms of the Museum in which it is situated and the nature of the collaborative studentship. As the experiences under study – that is meeting scientists – take place as part of a museum visit for the participants, a discussion of relevant museum education literature and learning theory is provided. In particular, I focus on face-to-face interactions along with relevant impacts on visitors of museum visits. Following a discussion of this broader literature, I give a short summary of the history and nature of the Natural History Museum, and describe relevant points around its education programme and strategy. I finish the chapter with a discussion of the modified Delphi study conducted at the beginning of this PhD research, which enabled me to integrate the interests, experience and expertise of those working at the Museum into the development of my research. I finish with a description of the research focus identified after this consultation with Museum practitioners.

Chapter 3 addresses the academic research relevant to this research focus and theoretical perspectives that could be adopted in order to address this issue. With the focus on the impacts of meeting scientists, this chapter looks at the roles scientists might or might not play in public engagement and the impacts of those roles on the people who are interacting with the scientists. Relevant theories used to explore the roles played by scientists include identity theory and interest development. Following this review, the two reframed research sub-questions are presented. The resulting research focus and sub-questions, therefore, represent a practitioner-identified problem approached using an academic lens.

Chapter 4 discusses the methods and methodology utilised in tackling the research questions. The study design is described, along with how participants were recruited, events selected and a justification for choices made. A particular focus in this chapter is given to the data collection methods used; interviews and production of field-notes. An overview of the data analysis techniques used is also provided. Throughout this chapter, relevant methodological perspectives and approaches are also highlighted.

The subsequent three chapters describe the data and findings reached through the methods discussed in Chapter 4. Each data chapter takes a different theme; the first two of the data chapters are guided by the research sub-questions, the final data chapter focuses on the longevity of impacts as included in the overarching research question. Chapter 5 addresses data around visitors' identification of scientists. This part begins with a discussion of what visitors were expecting of scientists and what impacts meeting a scientist had on their perceptions of scientists and on their subsequent descriptions. Key example case individuals are introduced to exemplify the different ways in which meeting a scientist had an impact on participants' perceptions of scientists. These individuals are returned to throughout the remainder of the thesis to illustrate points. It is concluded that visitors held multiple ideas about scientists; contrasting ideas seemed to be present simultaneously. The ideas of expertise, authenticity and exclusivity seemed to be important in the learning experience of meeting scientists and were valued by visitors; however, aspects of 'normality' and 'everydayness' also had significance, particularly when visitors were able to identify with scientists.

Chapter 6 discusses the data relevant to whether the meetings had an impact on visitors' identification with scientists. Data on how visitors identified links to the scientists are presented – visitors saw personal connections between themselves and the individuals. Visitors' positioning of themselves in relation to the scientist is also examined from interview and field-note data. Evidence of visitors, in particular A-level students, carrying out identity work – 'trying on' the identities of the scientists they met – is discussed. Finally, using the questions participants generated for the scientist they met as indicators of interest, I argue that visitors developed an interest in the scientist themselves as a result of the session. Findings suggest that visitors were keen to learn about the personal life and career history of the scientist rather than topics such as the techniques used in their study or the scientific content of their research.

Chapter 7 looks at the follow-up interviews more closely and at how visitors indicated longer-term impacts in their interview responses. The chapter looks at how visitors reported engaging with science after the museum visit. These occurrences of continued engagement are examined in terms of everyday engagement, which might be conversations with family or friends, paying more notice to wildlife in the local park or watching relevant television programmes. Follow-up engagement might also be in the form of in-depth engagement such as specific research into a topic relevant to the meet-the-scientist session. These incidences of continued engagement are discussed in terms of interest development, using principles from educational psychology, to conclude that, for some visitors, meeting a scientist is a trigger or a reinforcing experience for long-term interest development.

Chapter 8 concludes the thesis by returning to the overall aim of the research – to understand if and how meeting scientists might have an impact on museum visitors, with the aim of contributing to the knowledge around how to increase and encourage scientific literacy and engagement with science. The findings from the data chapters are synthesised; the discussion centres on meeting scientists as 'added value' in increasing scientific literacy and engagement. Key case individuals are also returned to and a more holistic picture of impacts on three examples is provided. It is concluded that meeting scientists had complex lasting impacts on visitors. The notion of 'everyday experts' is discussed following the emergent themes of expertise and 'normality' of the scientists from the findings. Implications for research are discussed, including how the research builds understanding of interest development as part of scientific literacy and engagement, and the influence of expertise in science identity work. I propose future directions for the roles scientists play in public engagement stemming from this research and propose a 'midway' for public engagement to incorporate the expertise and 'everyday' nature of the individual scientist simultaneously.

This thesis provides evidence to suggest that what is impactful is the experience of meeting an individual who is simultaneously an expert in a particular field, of which they can tell you much about, but also a person with many other interests, with their own family and friends, hobbies and shared experiences with which visitors can identify. Enabling visitors and students to access expertise alongside the personality of the individual scientist can lead to many complex and long-lasting impacts; these impacts may include developing perceptions, awareness, interest and motivations in science, contributing to scientific literacy and engagement with science.

Chapter 2: Research context and museums as places of impact

2.1 Introduction

This research is situated in the Natural History Museum, London; the study is funded through a collaborative studentship between the Museum and King's College London. The research focuses on activities – meeting scientists – and their impacts on visitors within the context of a museum visit. There has been a wealth of research conducted on museum learning; the setting of the current study requires a review of the relevant aspects of the museum literature.

Previous studies have shown that visitors attending a museum behave, learn, react and interact in certain ways: reviewing this work, therefore, will be relevant to my understanding of how visitors experience the meet-the-scientist events. This chapter examines the relevant literature on museum and out-of-school learning, before giving a brief overview of the significant developments at the Natural History Museum, London. The chapter concludes with the description of a modified Delphi study conducted at the beginning of this research in order to identify the most important and interesting research areas from the perspective of public engagement staff at the Museum.

2.2 Broad context: learning in museums and out-of-school settings

The work in this thesis relates to learning – how and what individuals learn during an experience at the Museum and concerns visitors' perceptions and attitudes towards science and scientists. This research, therefore, requires a discussion of what learning is and how individuals learn, particularly in museums and other out-of-school contexts. In this research learning is defined in a broad manner: learning includes affective, social and cognitive aspects, gaining information, skills and practices, developing attitudes, perspectives and social relationships. Learning can be seen as a change in, or strengthening of, a person's attitudes, interests, knowledge, perceptions, understanding and behaviours, compared to before the learning experience.

2.2.1 Museum learning: theories

A considerable amount of the early work into museum learning has been described as atheoretical and lacked strong grounding in one perspective (discussed in Anderson, Lucas, & Ginns, 2003). Following acknowledgement of this short-fall, research into museum learning since has typically been at one of two extremes – either heavily theoretical, or alternatively, focused on the outcomes and nature of visits without a strong theoretical grounding (as discussed by Bamberger & Tal, 2007). As research into learning theory has progressed and diversified, and as work has been applied to contexts outside the classroom such as museums, a number of different influential perspectives on learning have been developed and integrated into research studies. These learning perspectives include constructivism, sociocultural theories, ideas around situated cognition and the development of conceptual ecologies.

It is acknowledged that there are other approaches which may be discussed in the literature and referred to as learning theories, but which are not addressed here. These include, for example, Gardner's Multiple Intelligences and discussion of the different learning domains. Although these ideas are popular from the perspective of museum practitioners, these ideas are not theories *per se* – they do not enable one to make a prediction about outcomes – and researchers now argue that there is little empirical evidence to support the use of such approaches (see Adey & Dillon, 2012). I will not, therefore, return to these ideas; the theories discussed in the following review, beginning with constructivism, are arguably the most relevant and grounded for this research because they have been used, studied and developed within museum and school science education fields. The theories are, therefore, appropriate for the museum contexts which visitors will be situated within and have key strengths in terms of understanding the impacts of interactions with scientists in the current research.

i) Constructivism

In keeping with much of the museum education literature, I draw ideas from a constructivist learning perspective in which learning is socially constructed within a context. Piaget was a key influence in the development of constructivism, which builds on behaviourism and cognitive learning, arguing that learners construct their own perspectives and views on the world through individual experience (Piaget, 1959). Constructivism promotes learner inquiry and exploration, in preparation for problem solving in new situations. These principles have been applied to the development of museum exhibits in the Natural History Museum and elsewhere (for example Allen, 2004).

Constructivist learning theory has been applied to museum and other out-of-school settings, a phenomenon which has been explored extensively by George Hein in his book, *Learning in the Museum* (1998). A constructivist approach would argue that learning is constructed by, and exists within, the learner as opposed to knowledge being external to the learner. Key figures in constructivism include John Dewey, Jean Piaget and Lev Vygotsky. Constructivist museums, according to Hein, allow the learner to explore in their own way, following their own route through the exhibits and making their own connections between concepts presented. This perspective is in contrast to museums with a defined structure or path through the content and exhibition elements. Knowledge is built upon previous information and, therefore, comparisons are encouraged between new and prior experiences. An example of an exhibition strongly based on constructivist theory is 'Investigate' in the Natural History Museum, which encourages learners to ask their own questions of the collections and explore the information around the specimens to find answers. Whilst I question the extent to which an exhibition or activity could ever be truly constructivist in enabling visitors to be completely free and open to learning in their own way, I recognise the importance of building from previous experience and of individuals forming connections between concepts.

Socio-constructivism is a branch of constructivism that emphasises social negotiation and collaborative learning, with lead theorists in this approach being Garrison, Piaget and Vygotsky. The idea of socio-constructivism addresses one of the criticisms of constructivism as a learning theory – some learning may be co-constructed, that is members of a group may contribute to knowledge construction or change together; however constructivism only recognises that which is constructed within the learner themselves. Socio-constructivism begins to recognise the role that others play in the construction of knowledge: others influence the way learners construct knowledge by pointing things out, discussing things and offering new information (Rennie & Johnston, 2004).

Other approaches to learning theory build on the role of the social context further and, therefore, may be appropriate to consider when studying social experiences such as interactions with scientists in museums, for example the sociocultural approach.

ii) Sociocultural perspectives

Sociocultural learning supposes that individuals learn from one another, in a cultural setting. The main theorist behind sociocultural theory was Lev Vygotsky (1978), although Wertsch (1991) also developed many of the main themes from Vygotsky's original work.

Sociocultural perspectives on museum learning have been particularly influential in recent years in museum research, recognising the part that social interactions play on learning (Leinhardt, Crowley, & Knutson, 2002; Martin, 2004; Rennie & Johnston, 2004; Schauble, Leinhardt, & Martin, 1997). Sociocultural science education not only emphasises the social aspect of learning science, but also places importance on the recognition that science is a social human activity which takes place within cultural contexts and frameworks (Lemke, 2001).

Within a sociocultural approach, the focus of the study is not only on the individual visitor, but also the social context in which they operate: the group they attend with, the people they speak to during their visit and the nature of these interactions. Approaches to museum learning research using sociocultural theory, therefore, involve studying the group of visitors as a whole, rather than selecting one individual from the group or treating them as separate entities (for example see Allen, 2002). This is an interesting approach for the current research, as social interactions with scientists in the Natural History Museum, London, often occur within family or peer groups and, therefore, impacts can either be individual or shared within these groups of visitors. To exclude this social aspect of museum learning, I would argue, presents an extremely limited view of the impacts which might occur as part of an experience, ignoring what may develop as a result of conversations and interactions during and after the visit. A sociocultural perspective on learning is particularly relevant to identity theory, another theoretical perspective I take in this thesis, particularly in how individuals perform identity work and the influence on identity development of being recognised by others as a certain type of person.

There is also a growing literature base looking at learning conversations and talk amongst museum visitors based on sociocultural theory (Ash, 2003; Davidsson & Jakobsson, 2012; Leinhardt *et al.*, 2002) and approaches and findings from these studies are extremely relevant to the current study in terms of looking for evidence of impacts in visitor talk and questions in particular.

iii) Communities of practice and situated cognition

Research into communities of practice is another influential perspective which informs this study. Communities of practice are collections of individuals who share interests or concerns and whose social grouping facilitates socially-mediated learning through which individuals who are more novice to the field or area learn from those who are more experienced. Expertise is thus learned from other individuals through apprenticeship – induction into the community of practice and adopting the shared language of the field (Lave & Wenger, 1991; Wenger, 1999). Legitimate peripheral participation is the process by which less experienced or new members of a community learn from those more experienced, eventually becoming more involved in the community through involvement in more complex and important activities (Lave & Wenger, 1991). Communities of practice are sites of situated cognition, the idea that knowing is located within a particular activity and bound to a particular context. Communities of practice may also be sites of learning through intent participation – first-hand learning through doing, and discussing learning outcomes with others in the community of practice (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003).

Communities of practice offers an important perspective for this work as it helps describe processes of identity development and explains how sharing interests and language with others in the same community might enable individuals to develop a stronger affinity and identify more strongly as a member of that community. Indeed, research into undergraduate research programmes and their impacts on students' identity development in terms of becoming a scientist used the theories of communities of practice to explore how students undertake a cognitive apprenticeship, that is learning from more experienced members of the group (Hunter, Laursen, & Seymour, 2007). The community I imagine for this thesis is that of 'science people', those literate, engaged and interested in science. Communities of practice theories have been influential in thinking about identity development, discussed in Chapter 3: individuals construct meaning about themselves through their interactions with a community of practice (Holland, Lachiotte, Skinner, & Cain, 1998).

iv) Conceptual ecologies

Learning is a complex process, not only in the breadth of ways in which it can be facilitated, and the variety of times and environments in which it can occur, but also in the diversity of ideas and concepts that can be developed through learning. Stemming from conceptual change models of learning (for example Posner, Strike, Hewson & Gertzog, 1982), conceptual ecology theory is based on the idea that individuals hold a variety of ideas and perceptions which are relevant and drawn from at different times, to different extents in different contexts (diSessa, 2002; Reeve & Bell, 2009). The notion of conceptual ecologies is useful in that it illustrates how multiple ideas can be linked in the mind of an individual and be of greater or lesser dominance, in the same way that organisms in an ecosystem are linked and affect one another in varying ways and to varying extents. In this way, conceptual ecologies are of more use to the current research than theories of multiple conceptions (for example Driver, 1981; Driver, 1989). Conceptual ecology theory accords with the idea that learning is dynamic and context specific, as in social constructivism. Moving away from the idea of cognitive conflict, whereby conflict between two ideas leads to learning and development (Piaget, 1959), conceptual ecologies enable multiple ideas to be held at once within the same individual and used to varying degrees (Abd-El-Khalick & Akerson, 2004; Strike & Posner, 1992).

Previous studies have generated questions about how and where multiple conceptions might occur, and have documented areas where specific contrasting ideas have been held simultaneously. Reeve and Bell (2009), for example, demonstrated that children have a conceptual ecology of multiple ideas around the notion of 'healthy'. Palmer (1999) looked at students' scientifically acceptable and alternative explanations around the concept of 'biological role', the role or function each living thing has in nature. Studies such as Palmer's describe the ways in which 'every day' and scientific viewpoints are held concurrently within a conceptual ecology, and thus question notions of learning that depict everyday knowledge being replaced by scientific knowledge upon appropriate instruction

The notion of conceptual change has been used frequently in education, particularly within science (Abd-El-Khalick & Akerson, 2004; Posner *et al.,* 1982). The complexity of conceptual change is reviewed by Chi and Roscoe (2002), who describe the process of conceptual change as occurring laterally to new or different ideas, rather than hierarchically to 'better' or 'worse' conceptions. The theory that one 'incorrect' idea can be replaced by another 'correct' idea has, however, been challenging to implement within education and met with limited success. A conceptual ecology, conversely, allows for the existence of multiple ideas and suggests that it is the degree to which these ideas are used and the contexts on which they are drawn upon, which is important.

2.2.2 Defining museum learning

There are challenges in defining learning, partly due to the diversity of the fields in which learning arises, the multiple learning theories on which work draws, and the breadth of characteristics and processes learning can encompass. Previously there has been a predominant focus on outcomes, although this tends to restrict discussion of what learning really is to set areas or targets.

Learning in museums has attracted many different labels as researchers attempted to distinguish it from learning occurring in schools. The use of the term 'informal learning', to describe the learning taking place in such places as museums and science centres, and distinguishing it from formal learning, that which takes place within the classroom, has received criticism (Dillon, 2003). Arguments against the use of the term 'informal learning' include that terms such as informal and non-formal are actually of little real use to education researchers and practitioners in studying and facilitating learning, and are at risk of portraying a hierarchy of types of learning with one more significant than another. As such, these terms have become less widely used and alternatives have been suggested, for example learning outside the classroom and lifelong learning. Essentially, learning is learning, wherever it takes place; learning from schools need not have a separate label from that taking place in other contexts. So-called 'informal' and 'formal' contexts can be thought of not as producing different types of learning, but as providing different learning opportunities within a wider learning ecology of experiences (Bartels *et al.*, 2010). I, therefore, use the term learning here both to describe the experiences of visitors to institutions such as museums and science centres, and where relevant, the learning which might take place within formal educational settings and learning at home, for example through watching television.

In the definition of learning set out on page 29, learning is said to involve a change of some sort. This change is seen as contributing to an incremental and cumulative process of learning in which ideas are shaped, reshaped, evaluated, dismissed and altered in a continuous manner as a result of new experiences and information. There are different ideas about how learning might be achieved (discussed in Leinhardt & Crowley, 2001), and suggestions that learning can be rapid and significant, or more gradual (Anderson *et al.*, 2003; Mintzes & Wandersee, 1998).

In thinking of learning as a change of some sort, it is implied that individuals are only learning if they are experiencing something which makes them think differently to how they thought before. This assumption may be true in the case of visitors learning new knowledge or developing new interests as a result of a museum experience. This view of learning as change, however, excludes experiences which strengthen what the visitor already knows or feels. For example, exhibits or interactions experienced during a museum visit to a natural history museum may confirm and support visitors' concerns about biodiversity loss and strengthen their positive attitudes to conservation. The change taking place here is not one which shows a *difference* in ideas compared to before, but the learning manifests in *strengthening* of knowledge and attitudes. There is a growing awareness (for example discussed in Falk, 2004) that museum learning does not necessarily always lead to new knowledge, but perhaps that museums can induce a change in, or strengthening of, existing attitudes, interests, knowledge, perceptions, understanding and behaviours compared to before the experience.

Learning takes place throughout the lives of individuals and is not bound to certain institutions, ages or activities. There is an increasing recognition that learning is a lifelong process and not only confined to the years one is in formal schooling – therefore, presenting an opportunity for the science education field to make science relevant and inviting to all ages (Rennie, 2011). Learning is also shown to be more effective and long-lasting when experiences reinforce one another and when opportunities to continue learning are presented. For example, researchers recommend developing prompts and suggestions in exhibit labels which provide students with opportunities to connect their learning to their home and school life during a tour in a natural history museum (Cox-Petersen, Marsh, Kisiel, & Melber, 2003). The importance of understanding the links between school and out-of-school learning opportunities has also been stressed in terms of raising scientific literacy (Lucas, 1983). Research into how best to join up individual experiences within a wider network of learning activities has been conducted, particularly focusing on the relationship between museums and schools, collaboration between teachers and educators, and enabling students to make connections between learning in both (Bamberger & Tal, 2008b; Eshach, 2007; Tal, Lavie Alon, & Morag, 2014).

2.2.3 Museums as part of learning ecologies

In relation to how people learn and the contextual nature of learning, this work adopts the idea of a learning ecology: learning is seen as many inter-related experiences occurring over time and in a variety of different contexts (Barron, 2004). These learning experiences might include museum visits, school, television programmes, workplace training and conversations with family or friends (Barron, 2006b). I find Barron's work useful, particularly in the way she defines learning ecologies:

> *The accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide opportunities for learning.* (Barron, 2004; p. 6)

I, like Barron, consider the role of relationships in learning to be important, as it recognises the role of others and social influences on learning, as well as 'the person as the central organizing central node in the system' (Barron, 2004; p. 6).

There are three key themes relating to learning ecologies which are relevant to this study, as identified by Barron (2006b). The first is the relationship between interest and learning. Interest is especially important in self-directed learning which occurs throughout life and in any number of different situations, as opposed to learning directed by someone else, usually a teacher or parent. Sparking interest in a particular area motivates people to find out more, to engage further and, therefore, to learn.

The second theme is the diversity of strategies people use to follow-up their initial interest once it is ignited. A learning ecology approach requires that we look beyond the traditional or familiar opportunities for learning, for example reading books or asking teachers, but also consider how people might learn in many different ways throughout their lives. This approach requires a very open perspective on research, not to limit or predict the kinds of learning impacts an intervention might have.

The third and final theme in learning ecology approaches is boundary-crossing as a result of interests. Learners may be encouraged to continue their learning beyond the initial experience, to follow their interests and, therefore, be motivated to engage in new contexts and communities. Learning does not occur in isolation, and not all learning happens in schools. Work into boundary-crossing focuses on how to merge and link the concepts of each experience and integrate the activities; for example, ensuring students are prepared for a museum trip before leaving the classroom and engage in follow-up experiences when they return (Anderson *et al.*, 2003; Griffin, 2004). Museums and other learning institutions have faced difficulties in trying to measure the impacts of a visit to their institution and separate these impacts from learning taking place as a result of another experience. Seeing each learning experience as one element in a wider network of experiences is more realistic and representative. Work into boundary-crossing has led to the suggestion that teaching approaches grounded in students' everyday knowledge can have significant impacts (Barton & Tan, 2009; Lee, Luykx, Buxton, & Shaver, 2007). For example, students who were able to make more links between in-school and out-of-school science learning experiences demonstrated higher levels of interest, self-efficacy, achievement and perseverance in learning science compared to students who did not identify links between different learning experiences (Tran, 2011).

The adoption of the idea of learning ecologies in the museum and informal science learning fields has led to further calls for institutions to work more closely together (Falk *et al.*, 2012; Mattherson & Holman, 2012). Researchers have also discussed how best to integrate different educational settings such as museums and science centres with schools so as to maximise the benefits gained from learning experiences (Braund & Reiss, 2006; DeWitt & Storksdieck, 2008; Lucas, 1983). The creation of the Centre for Informal Learning and Schools (CILS), a research collaboration between King's College London, the San Francisco Exploratorium and the University of California Santa Cruz, highlighted the need to integrate research about learning outside the classroom with how experiences such as museum visits have an impact on education within school (Bevan & Dillon, 2010; Martin, 2004). The integration of research from multiple disciplinary perspectives has previously been seen as problematic in terms of looking at the impacts of school visits to museums (Martin, 2004). I would argue, however, that it is necessary in settings such as museums, that researchers can draw upon a wider base of knowledge from a variety of approaches. Ellenbogen (2013) argues that convergence of the fields of science communication and learning in out-of-school contexts will lead to them being stronger than the sum of their parts due to their shared goals. The current research, therefore, will draw from work in museum studies, science education, educational psychology and science communication fields.

2.3 Impacts of museum visits

Just as learning encompasses a breadth of different aspects, there is a diversity of potential impacts that may result from a museum visit. In this section I highlight some of the main ways museums have been shown to have an impact on their visitors. This section draws mainly from work carried out in museums as my research is based within a museum context, although relevant studies from other learning experiences are also included, such as science centres, laboratory visits and zoos and aquariums. There is a prevalence of work on families and school groups in particular, as these are the two main audiences for many museums (including the Natural History Museum, London) and, therefore, are the focus of much museum and out-of-school learning research.

The majority of research into learning in science museums has focused on cognitive learning – accumulation and recall of knowledge and concepts – arguably due to the focus on school visits to museums. There is, however, a wider range of impacts of museum visits than individual cognitive knowledge gain, including affective, social and behavioural outcomes. The broad range and unique nature of possible impacts of museum visits is illustrated nicely by the following quote from Rennie and Johnston (2004; p. S5):

If museums and similar institutions are to impact on people's lives, then they must change people in some way. A person watching a cuttlefish for the first time at an aquarium might be struck by how rapidly it can alter its color. A visitor viewing another exhibit may be shocked at the number of marine species threatened by the destruction of coastal sea grass due to pollution, and subsequently join an environmental group. Both people experienced a change. The first might simply remember, when helping with a child's science homework at a later time, that cuttlefish can camouflage themselves. The second may build upon the aquarium experience and become a committed conservationist for life. And many other visitors may experience impacts between these two extremes.

The breadth of outcomes of learning science in contexts such as museums was also highlighted in the National Research Council report *Learning Science in Informal Environments* (Bell *et al.*, 2009). This report by Bell *et al.* was a crucial and timely documentation of the impact of learning science outside the classroom, in a period of financial instability for many of the institutions reviewed. It included strands around identity and interest previously overlooked by other reviews and in this way is particularly relevant for the current research. The review discusses how museum experiences, such as an interaction with a scientist, might lead individuals to shape the ways they see themselves and hope others see them.

Whilst it is noted that the report attracted criticism, however, due to its focus on Western culture and, therefore, its limited application outside of the Westernised world (Kisiel & Anderson, 2010), its discussion of museum contexts similar to the Natural History Museum, London, make it a useful reference source for this thesis.

A catergorisation of the types of benefits that may be realised when considering learning and engagement in the context of a novel science setting is provided by April Luehman's work (2009). The categories, identified from a literature review and supported by a study of school pupils attending a laboratory workshop, are (abbreviated titles added in parentheses):

1. Improving science content knowledge (*Science content knowledge*);
2. Positive impact on students' understanding of the nature of science and scientific inquiry as well as scientific reasoning (*Understanding scientific inquiry*);
3. Encouraging students' interest and motivation in science by helping them to develop a sense of scientific appreciation and literacy as well as an awareness of possible career opportunities in science (*Individual interests, motivation and attitudes*);

4. Providing the opportunity to access scientific tools and practices that are used by practicing scientists (*Authenticity and experience*) (p. 1834).

Luehmann's categories are useful in discussing the impacts of out-of-school experiences as they are directly relevant to science and, therefore, more specific than some of the other categorisations of the impacts of museums in general. These benefits did not originate from research in museums, however, they are still useful when thinking about museum learning; the out-of-school laboratory experience had many similarities with museum experiences in that it was novel, stimulating, and provided access to authentic objects, information and activities. Whilst Luehmann focuses on students, these potential impacts apply to a broader audience including adult visitors to museums. Arguably, however, there is one additional group of impacts of museum experiences missing from the categorisation from Luehmann that would be pertinent to the context of museum-based experiences: social roles and interactions. Museum learning literature has stressed the importance of social interactions during the visit and as an impact of a visit (for examples see Leinhardt *et al.*, 2002; Packer & Ballantyne, 2005; Zimmerman, Reeve, & Bell, 2010). I, therefore, use Luehmann's four categories, plus an additional category around social roles and interaction, to guide the review below of learning impacts for visitors to museums and out-of-school contexts.

2.3.1 Science content knowledge

Visitor research has predominantly focused on the cognitive gains of museum visits and out-of-school learning. A recent study, to give one example, demonstrated positive impacts on children's knowledge about animal care and conservation following a summer camp at a zoological institution (Bexell, Jarrett, & Ping, 2013). Differences between pre and post survey responses indicated a positive impact of the five-day camp activities on children's knowledge about how to protect animals, alongside other impacts such as increased empathy. In an earlier study, Kapon, Ganiel and Eylon (2010) looked into the impacts of public physics lectures on participating adults. Audience members reported developing new scientific knowledge, felt that they had gained a new way of thinking and thought that the experience had been exciting and interesting.

Researchers are not only interested in whether students can recall science content knowledge immediately after the experience, but also after some time. Bamberger and Tal (2008a), for example, have looked into the outcomes of a visit to a science centre 16 months after the visit. They found that students could remember a similar amount of detail compared to what they remembered directly after the experience and could attribute learning to the exhibitions and social interactions they experienced (Bamberger & Tal, 2008a). I share Bamberger and Tal's focus on the longer-term impacts of museum experiences and emphasis on the breadth of these potential impacts, not only cognitive gains. However, I would disagree with their argument that more research is needed on the longer-term impacts of school visits in particular. I would argue that actually more research is required across audiences, not only school groups, on the longevity of broader impacts such as identity and interest development.

In recent years, having identified that learning was taking place during museum visits and lasting afterwards, researchers have increasingly turned their attention to how this process of learning was taking place. In their paper looking at factors which can affect or predict learning impacts for a visit to a natural history museum, Bamberger and Tal (2008b) found that social interaction, personal relevance of the content to the lives of the students, and prior knowledge together had the most significant influence over the learning outcomes. A number of other factors have been identified which may have an impact on learning in the museum context (DeWitt & Storksdieck, 2008). These factors have been offered as explanations for some of the differences in the type or extent of learning between individual visits or visitors and include: the novelty of the experience or setting; orientation within the museum; social interactions; prior knowledge of the pupils and their interests and personal agendas. Falk and Storksdieck (2005) also list 12 independent variables that may have an effect on the visitor's experience. These factors include: prior interest, knowledge and experience of the visitor; visitor expectations and motivations; design and exposure to exhibits and programmes; physical environment and social mediation. A selection of these factors are discussed further below.

Visitors come to museums with a variety of prior experiences and knowledge about the subject area, museums in general, or the particular museum that they are visiting. Falk and Storksdieck (2005) argue that knowledge gains as a result of museum visits may be functions of prior interest and knowledge. Similarly, Tunnicliffe, Lucas and Osborne (1997) stress the importance of museums and zoos seeking to understand visitors' prior knowledge and interests in order to more effectively communicate their message. Subsequent studies have confirmed the role of prior experience and knowledge in learning in museums, demonstrating that families use a wide range of different knowledge types and experiences to make sense of exhibit content (for example Zimmerman *et al.*, 2010). Zimmerman *et al.* used observations and pre- and post-visit interviews to explore the ways in which families constructed meaning around the biological content of the exhibitions they engaged with. The study indicated that families transferred knowledge from different shared contexts and experiences to make sense of the content they were encountering, using examples from everyday activities such as television, summer camps and jobs (Zimmerman *et al.*, 2010).

Despite the evidence above suggesting that prior experience and relevance seems important in museum and science learning experiences, research from the Exploratorium in San Francisco suggests otherwise (Gutwill-Wise & Allen, 2002). Researchers attempted to adapt an exhibit to include either a narrative - a personally relevant story, or inquiry – which encouraged questioning at the exhibit in the hope of prompting visitors to reflect on how the exhibit content fitted with their own experiences. Findings indicated that the narrative intervention did not make a consistent difference to the learning or behaviour of the visitors at the exhibition, compared to the baseline (Gutwill-Wise & Allen, 2002). The contrast between these findings and those above, which support the role of personal relevance and prior knowledge in exhibitions, demonstrates the complexity of learning and dilemmas faced in designing learning experiences – learning may build on prior knowledge, but in order to facilitate the development of understanding from prior knowledge, adequate context and framing must also be provided.

2.3.2 Understanding scientific inquiry

Museums, with their collections, exhibits, programmes, workshops and staff, provide an important opportunity for visitors to learn about the nature of science, the processes involved in scientific research and the skills of scientific inquiry and reasoning. When Luehmann (2009) asked secondary school students (aged 11-18) what they felt was the most important thing they had learned during an out-of-school laboratory workshop, the largest group unsurprisingly chose the scientific content (n = 114), however, the second and third largest groups chose the scientific skills (n = 54) and learning about the nature of science (n = 49). In another workshop, this time focused on computer-based science and technology, elementary school students (aged 5-13) exhibited evidence of developing inquiry skills, problem setting and solving, and persuading their peers about their views – demonstrating their reasoning skills (Bencze & Lemelin, 2001). These studies of student workshops indicate that there is potential for the development of scientific inquiry skills and the appreciation of the nature of science as a result of out-of-school experiences.

The opportunity to engage with authentic specimens, equipment, science research and science problems is one offered by many museums, science centres and open laboratory visits, particularly in the form of workshops or behind-the-scenes tours. For example, a visit to the interactive 'pod' at the Centre of the Cell in London, presents students with a chance to work through problems faced by the scientists who work at Queen Mary, University of London. The route students take to enter the pod takes them above the research labs of the university, providing a chance to see real scientists at work, before having a go at similar simulated problems themselves. Braund and Reiss (2006) argue that science learning outside of school has the potential to complement school-based education with more authentic experiences. The researchers suggest that museums should make the most of their artefacts demonstrating science in the making, showing the process of science and the social nature of scientific research (Braund & Reiss, 2006). They particularly emphasise the use of stories alongside objects to show how science knowledge is generated; such stories, they argue, could be incorporated into meet-the-scientist sessions in museums such as those studied in the current research.

Science communities are places of inquiry and investigation. The conversations visitors have with one another, and potentially with museum experts, during and following the visit, are themselves important learning impacts, facilitating the development of skills and knowledge relating to the nature of science and scientific inquiry. Often, exhibit and programme designers aim to promote socially mediated activities (Allen & Gutwill, 2009; Tenenbaum, Prior, Dowling, & Frost, 2010). Such an intervention may involve science centre exhibits which need more than two visitors interacting to make them work, or programming such as Nature Live at the Natural History Museum, London. New initiatives to promote group inquiry at science museums and centres build on work from the Exploratorium, San Francisco. This work shows that after training in inquiry games, groups developed better social inquiry skills, including asking questions around exhibits and interpreting results (Gutwill & Allen, 2010a; Gutwill & Allen, 2010b). Other researchers have shown that the environment of museums and science centres can facilitate the development of inquiry and investigation skills, along with interpretive and meaning-making talk (Haden, 2010; Sanford, 2010).

2.3.3 Individual interests, motivation and attitudes

Museums and out-of-school learning experiences can have affective as well as cognitive outcomes, influencing elements of identity such as attitudes, interests, motivations and enjoyment relating to science.

i) Interest

Museums and science centres are places in which interest development can occur; new content and information is encountered and interests may be triggered, or opportunities might be offered for existing interests to be pursued. Researchers suggest that by allowing and encouraging students to learn in a self-directed and natural way by pursuing their own interests and curiosity, they will gain more from the experiences, and that this may increase positive attitudes and increase interest in school science (Braund & Reiss, 2006; Griffin, 1998). Indeed, Jarvis and Pell (2005) reported that students' interest in space and science in society increased after their visit to a space centre, although they did note that interest was dependent on gender, with girls showing more gains in positive attitudes towards space after the visit compared to boys. Another example, used in the current work, is research by Niels Bonderup Dohn (2011; 2013), which examines the factors contributing to interest development as part of visits to zoos and aquaria. Interest development theory is discussed further in section 3.4.2.

ii) Enjoyment

Enjoyment is an affective outcome of a learning experience that is likely to improve learners' attitudes and engagement in other areas. For example, teachers accompanying students on a laboratory visit in a separate study identified that the experience had a positive impact on students' affect, motivation, enjoyment, interests and participation, when asked about the experience afterwards (Luehmann & Markowitz, 2007).

Enjoyment as an impact of a learning experience links to the notion of learning for fun: the process of learning itself is enjoyable. Learning for fun involves seeking an experience where 'education is entertainment, discovery is exciting and learning is an adventure' (Packer & Ballantyne, 2004, p. 68). When adult visitors to a museum, national park or aquarium were asked about their experience in short interviews, the most endorsed of 10 statements was: 'Learning in the museum/park/aquarium is an enjoyable way of spending time' with 92% agreement (n = 52) (Packer, 2006). When visitors were asked what made their learning experiences enjoyable, four themes emerged: a sense of discovery or fascination; appealing to multiple senses; the appearance of effortlessness (learning without realising it); and the availability of choice.

Enjoyment may be an immediate reaction to a museum experience, but research has also focused on how long the positive affective impacts last after the visit is over. In Jarvis and Pell's study, mentioned above, although attitudes were initially changed in a positive way after a school visit to a science museum, the changes were not long-lasting and disappeared within five months (Jarvis & Pell, 2005). Jarvis and Pell's findings suggest that impacts over time may vary from immediate impacts. Clearly, this is of concern to the field and of particular interest to funders. To make the argument for money well spent, institutions are keen to claim impact. Without longitudinal research studies to examine the effects of time-lags the field is unable to justify claims of impact.

iii) Attitudes

Linked to interest and enjoyment, museum visits may also induce attitudinal change. Brody, Tomkiewicz and Graves (2002) looked at visitors' attitude and value development following a visit to Yellowstone National Park. Findings indicated that visitors developed a more complex value system, with new values in terms of appreciation and wonder for the park, concern for the environment not to be exploited, and appreciating the benefits to humans of the area and of the research carried out there. These values were based on the initial attitudes of the visitors to the area's natural beauty (Brody *et al.*, 2002). In contrast, a study into the impacts of a visit to Disney's Animal Kingdom on visitors' attitudes to conservation and intended conservation actions had small but limited effects (Dierking *et al.*, 2004). Researchers concluded that 'the motivation required to engage in environment-friendly activities is a complex function of interest, knowledge, experience, concern and commitment developed over a lifetime' (Dierking *et al.*, 2004, p. 339), and that the impacts had not been as widespread or long-lasting as predicted. Research reports positive attitudinal change as a result of visiting a museum, but it should not be forgotten that there is also the possibility of negative attitudinal change as a result of a visit (for example Jarvis & Pell, 2002).

A later study demonstrated how adults attitudes to science changed following a visit to a science centre in Perth, Australia (Rennie & Johnston, 2007). Interview responses indicated attitude changes under three themes; connections with how participants remembered science being taught at school; finding science and technology more meaningful and enjoyable than previous experiences; and, finding science and technology easier to understand (and, thus, appreciating the role of science and technology in everyday life). These findings suggest positive impacts of a science centre visit on the attitudes of its adult visitors, particularly around how relevant and important they felt science and science research were. It is important to note here, however, that data were collected after the visit only; data on pre-visit attitudes were self-reported following the visit. Findings should, therefore, be treated with an element of caution as to whether participants felt pressured to report a change of some sort in their attitudes. A repeated study collecting pre-visit attitudes before the visit began might have been useful for strengthening these conclusions.

2.3.4 Authenticity and experience

Environments such as museums, science centres, open laboratories and field sites have the potential to bring visitors into contact with authentic objects and practices used in modern scientific research. For example a museum collection may contain scientific instruments and views into laboratories meaning that visitors can experience the actual setting where research happens. The importance of authenticity has been stressed in relation to the impacts of interacting with museum exhibits and collections (Leinhardt & Crowley, 2001).

Braund and Reiss (2006) advocate for experiences where students can be taken out of the classroom to participate in science and experience it as everyday practice in the space in which it is conducted. The benefits which may result from authentic science experiences outside of the classroom include access to rare material, 'big' science and extended practical work. There is a challenge in bridging the gap between school science and authentic science.

One authentic science learning experience for a student might be meeting a scientist and having the opportunity to ask them about their work. Researchers have suggested that interactions with experts in the field may be a factor which would optimise learning for museum visitors (Cox-Petersen *et al.*, 2003). Research highlighting the potential learning impacts of meeting experts is extremely relevant to the proposed study, where the impacts of interactions with museum scientists on visitors to a natural history museum will be investigated.

2.3.5 Social roles and interactions

The impacts discussed above operate on an individual level; however there are also impacts of museum visits which operate on a group or social level. Some of these social impacts arise during the visit and others manifest afterwards. Impacts may take the form of conversations with other members of their family or group of friends, interactions with visitor services staff, or discussions with educators, presenting staff, volunteers or experts. Research into family learning in museums has focused attention towards the social impacts of visits and interactions between visitors as they learn and take part in learning conversations (for example Leinhardt *et al.*, 2002). As learning conversations take place, different identities and roles are adopted by the members of the group. Children, for example, may adopt the role of an expert in a topic they know more about than the parents. Crowley and Jacobs (2002) call these topics 'islands of expertise' and describe how children use these developing interest areas to work on their own identities as people who are more or less interested in particular topics compared to other individuals during museum visits.

A pertinent study for the purpose of the current thesis was conducted at the Vancouver Aquamarine Science Centre in Canada, where Briseño-Garzón, Anderson, & Anderson (2007) chose to focus on the adults in a family group rather than the children as is more commonly the case in the visitor studies literature. I agree with Briseño-Garzón *et al.*'s comments that there is a dearth of literature focusing on adults visiting museums. I would go one step further, however, and suggest that research foci need to be even broader and examine adults visiting outside of family groupings – with friends, with partners or alone.

Despite the research demonstrating the social implications of learning in museums, it is not to say that those visiting alone do not learn. Packer and Ballantyne (2005) looked into the social dimension of learning in museums and suggested that both social and solitary learning can be beneficial to learning experiences, but in different ways. For example, solitary visitors have the opportunity to reflect; those visiting in groups have the opportunity to discuss ideas.

2.3.6 Summary of museum impacts

The review above demonstrates that out-of-school science learning experiences such as museum visits can have a breadth of impacts and highlights the complexity of these impacts. It has been useful for the purpose of structuring this review to break down the impacts into the five sections above, however there is a great deal of overlap between these categories and they are by no means mutually exclusive. For the purposes of designing a research study, it is useful to draw these themes together and think about the impacts of museum experiences holistically.

Thinking holistically requires considering the many impacts that can potentially arise as a result of a museum visit (Falk, 2004). Research needs to explore a wider range of impacts than currently studied, using a plurality of research methods (Rennie & Johnston, 2004). A holistic approach would look at the whole family or peer group over the whole visit and beyond, not only focusing on one exhibit at a time. Impacts must be considered within the context of the visitor's lifetime and not just immediately afterwards (Rennie & Johnston, 2004). Impacts may change over time and long-term outcomes are not predictable from short-term effects; researchers have identified three time periods for collecting data: from visitors' pre-museum history; visitors' in-museum experience; and visitors' post-museum history (Falk, 2004; Falk, Scott, Dierking, Rennie, & Jones, 2004). Researchers looking at dialogue events have made similar arguments for a need to look at long-term impacts (Davies, McCallie, Simonsson, Lehr, & Duensing, 2009), and the design of the current research follows recommendations from these studies.

Thinking holistically also embraces the idea that there may be negative impacts from museum and out-of-school learning experiences, not only positive impacts. The categorisation from Luehmann (2009) is useful, however it focuses solely on the *benefits* of out-of-school laboratory visits. There are no categories addressing possible negative impacts of the experiences; other impact frameworks reviewed were similar in their foci. Little research has been carried out on negative implications of museum visits, presumably as research has been striving to demonstrate positive impacts to justify the existence of museums to funding bodies and explore how visits can be developed to maximise positive impacts on visitors. It should be noted, however, that there is the possibility for negative impacts on visitors, against the hopes of practitioners, and this should not be ignored when conducting research such as the current study.

The impacts of museum and out-of-school learning experiences reviewed above are all relevant to the identities of the visitors. For example, improving science content knowledge is related to the content resources and background an individual can draw from, their understanding and awareness of the subject, and relative expertise in the field. In encouraging a visitor's interest, motivation and appreciation in science and science careers, impacts are around individual interest, attitudes and values, which form the basis of identity and drive internal motivation. Finally, providing authentic experiences with scientific tools and practices gives individuals the opportunity to construct their own science identities, surrounded by the real and authentic artefacts of science culture, seeing themselves as closer to science and scientists. Social impacts are related to individuals' roles relative to one another and their identity within a group. Every museum visitor may come away with a different impact, driven by the experiences and perspectives they arrived with. To summarise, therefore, museums can be seen as sites of complex and inter-related impacts which lead to the development of many aspects of identity.

2.4 Museums as places of identity work

The impacts of museum visits discussed above relate to individuals' identities, suggesting that museums have a role in the shaping and developing of visitors' identities. What follows is a discussion, therefore, of relevant identity theories that may be of use in situating this research. I then discuss museums as places where development of identity, or 'identity work' might be carried out, discussing research into identity work and framing impacts of museum visits as impacts on visitors' identity.

2.4.1 Identity

Identity is the way individuals see themselves, who they believe they are, and who they portray themselves to be to others (Holland *et al.*, 1998). Themes from identity research relevant to this work include identity work and development, self-perception and self-image, and identification with other individuals. In particular, I find the literature from Dorothy Holland on identity particularly useful in providing a theoretical grounding in terms of thinking about how museum experiences enable visitors to develop and shape their own identities in relation to the activities, information and other individuals with which they engage. Holland uses the work of Vygotsky and Bakhtin and stresses that identities are unfinished and in progress, occurring within social practice. Holland writes:

> *People tell others who they are, but even more important, they tell themselves and then try to act as though they are who they say they are*. (Holland *et al.*, 1998, p. 3)

Museums can, therefore, shape individuals' identities through the process of identity work. The notion of identity work was coined by Judith Howard (2000) in her discussion of how identity was 'done' or carried out. Identity work is said to be 'the processes through which we construct, maintain, and adapt our sense of personal identity, and persuade other people to believe in that identity' (Rounds, 2006, p. 133).

2.4.2 Museum impacts as identity changes

As visitors experience and reflect upon museum experiences, any impacts will affect their identity in a variety of ways. Here I am not arguing that one visit to a museum changes the type of person the visitor is. Rather, through this discussion, I wish to argue that the impacts of museum visits may affect elements of visitors' identities, their interests, attitudes, behaviours, knowledge, links to prior experiences, preconceptions and expectations. Impacts may manifest themselves in small changes to the individual elements which make up a visitor's identity. These changes may be positive or negative, strengthening or challenging the previous norm. They may be long-lasting or they may have evaporated before the visitor has left the museum. An examination of the outcomes of museum visits using the lens of identity provides a flexible framework through which the diversity of outcomes can be explored. Such an approach ensures the focus remains on impacts on individual visitors and their development within the social context of the museum visit, and allows for impacts to be complex and overlapping.

The concept of identity has been used to attempt to understand the differences between visitors to museums, exploring their interests, motivations and learning. Falk's identity-centred approach describes five types of museum identities visitors might adopt, but points out that people may be a mixture of more than one or different identities on different days (Falk, 2006). These identities are: explorers, facilitators, professional/hobbyists, experience seekers and spiritual pilgrims. The identities are said to influence the types of behaviours visitors exhibit when attending a museum and, therefore, the learning impacts developed as a result of the visit. Criticisms of the use of identity to categorise visitors have been expressed in terms of the limitations of segmenting visitors according to identity, which is seen as short-sighted and reductionist (Dawson & Jensen, 2011). Dawson and Jensen advocate a model that incorporates more of the complexity of identity. Others argue that while identity might be used as a predictor for museum-visiting behaviour it might also be something visitors explore, develop and 'find' in the museum itself and museums are important vehicles for the expression, confirmation and definition of identities (Paris & Mercer, 2002). This is a stance with which I also agree, and use the idea of 'identity work' in the current research to conceptualise how visitors' identities might be shaped as part of their museum visit.

Identity theory was used by Jay Rounds (2006) in exploring how visits to museums could enable individuals to carry out identity work: 'trying on' new identities and exploring the fit between new identities and their own self-image. In this way, museum experiences and identity affect one another in a circular process; visitors are seen to be continuously maintaining their existing identities but also developing foundations for future identities (Rounds, 2006). Identity is, therefore, flexible, dynamic and constantly changing – a set of properties from an individual's interactions with their environments. In relation to science learning experiences, museums might, therefore, be a place in which people can 'try on' being a scientist or being someone engaged with science.

In being a space in which individuals can 'try on' new identities, museum visits and out-of-school experiences may foster positive scientist identity development in students (Rounds, 2006). Students who hold a positive science identity have a positive attitude towards science, seeing themselves as a science learner and/or considering a future career as a scientist (Krogh & Andersen, 2013). The development of positive science identities in students is important in thinking about encouraging the next generation of scientists and also citizens who are confident to engage with science. For example, students visiting a laboratory workshop at a local university stated that the experience had enabled them to 'feel like a scientist' and expressed enthusiasm about the opportunity to become a 'real scientist', showing the development of identities as science learners or possible future scientists (Luehmann, 2009).

Identity work operates within certain restrictions. An individual can only adopt or work towards a certain identity if it is desirable and attainable, and when they can identify with others with that identity (Holland *et al.*, 1998). Identifying with others with the same identity and seeing them as 'like me' is the difference between adopting a label and embracing an identity where members share values, beliefs, actions and perceptions (Holland *et al.*, 1998). Using the example of alcoholics, Holland discusses how new members of Alcoholics Anonymous (AA) must identify with other members and their stories in order to be able to fully embrace the identity of an alcoholic themselves. *The Big Book* contains a collection of the stories of alcoholics, first published in 1939 with the fourth edition published in 2001, and is a tool for new members of AA to use to begin to see how they might be similar to existing members. Providing stories and information about other members of a certain identity can also work the other way, however, convincing people that they are not like the person they hear about. The use of stories and personal information as a tool in identity work is relevant in the current research, which explores the impacts of sessions where scientists share their own experiences and backgrounds with visitors. Depending on the information and visitor, therefore, these stories may lead to closer identification with scientists or distancing away from a science identity.

2.4.3 Summary of museum learning and identity literature

To summarise, the literature on out-of-school learning experiences was reviewed, concluding that the impact of experiences such as museum visits are broad and complex (reviewed by Rennie & Johnston, 2004 and Bell *et al.,* 2009; illustrated by Luehmann, 2009). The current research, therefore, uses open data collection methods which allow for broad and unexpected impacts to be explored and analysed, such as semi-structured interviews and iterative 'bottom-up' data coding.

There is a dearth of research documenting the impacts of museum experiences on adults (with the exception of Briseño-Garzón *et al.*, 2007; Rennie & Johnston, 2007). This gap in the literature supports a decision to conduct research with adult museum visitors in the current work. The lack of studies involving adults in museum learning literature also provides justification for the incorporation of literature from the science communication field in which adults are more often studied (for example Zorn, Roper, Broadfoot, & Weaver, 2006; Zorn, Roper, Weaver, & Rigby, 2010; Davies *et al.*, 2009) and, therefore, a field from which visitor studies could learn from. Another gap in the literature was identified in terms of longer-term research into the impacts of museum experiences (with the exception of Jarvis & Pell, 2005; Bamberger & Tal, 2008a; and called for by Falk, 2004; Falk *et al.,* 2004; Rennie & Johnston, 2007). Such a lack of research studying beyond the immediate impacts of museum experiences informed the decision taken in the current work to conduct a third interview two months following the interaction with the scientist.

Studies into out-of-school experiences have highlighted the potential impacts on learners' science identities (for example Luehmann, 2009), and work into museum learning has indicated that museum contexts may provide opportunities for identity development, or 'identity work' (Rounds, 2006; Bell *et al.,* 2009). In this way, prior research has led to the framing of the current study in terms of examining the impacts an interaction with a scientist might have on identity development of visitors, including identification of and with scientists. Specifically, previous literature suggests that areas of potential impact could include increased understanding of scientific concepts and research (Bamberger & Tal, 2008a), increased positive attitudes towards science and scientists (Rennie & Johnston, 2007), and increased interest in science (Jarvis & Pell, 2005).

Considering these impacts from the perspective of identity, museums are presented as important places in which identities may be shaped and developed. Until now the discussion has remained general to museums and out-of-school learning experiences and not specific to a particular context or environment. What follows is an overview of the particular context in which the current research is based: the Natural History Museum, London.

2.5 Local context: the Natural History Museum, London

As mentioned above, this PhD research was carried out in collaboration with the Natural History Museum, London. The Museum has undergone a number of developments in recent years which are relevant to the current research. A brief discussion, therefore, of the history of the Museum, the development of the education strategy and the evolution of research and evaluation carried out at the Museum, is useful to illustrate the background to the current research.

Natural history museums in general have faced the need to respond to changing societal and cultural trends, for example, most recently the rise in digital technology and the access to information over the internet. The aims of natural history museums are located around three main areas - to produce research, to teach and train new researchers, and to educate the public (Delicado, 2010). As developments have shaped natural history museums, the relative importance of these three aims has fluctuated. More recently, museums have played a role in engaging visitors, providing space for dialogue, developing scientific literacy and empowering citizens to make decisions around and within science, alongside the curation of collections and scientific research (Watson & Werb, 2013). Natural history museums, therefore, are currently apt places for the study of public engagement and its impacts on scientific literacy.

2.5.1 A brief history of the Natural History Museum, London

The Museum was formed of the natural history collections of the British Museum in Bloomsbury, with Richard Owen championing the establishment of a separate museum for these collections. After the full opening at the South Kensington site in 1883, the Museum continued to grow, new specimens were gained for the collections, increasing storage and research facilities were required and teams and departments developed. The origins of the Public Engagement Group, where I am now situated, began with the Department of Public Services in 1975, then becoming the Department of Exhibitions and Education in 1994. The Public Engagement Group was established in 2004.

The Museum has over 70 million specimens in the collections and employs around 850 staff, including more than 400 science staff who carry out research at the Museum and 350 public engagement staff. The Science department generates a significant amount of work, particularly within the fields of taxonomy, conservation, biodiversity and evolution; the department had 807 peer-reviewed papers published in 2011/2012 (Natural History Museum, 2013b). Over 80 PhD students work in the Science department, but so far this study is the only doctoral research undertaken under the aegis of the Public Engagement Group.

In 2013/2014 the Museum received five and a half million visitors. The public areas of the Museum include permanent exhibitions such as the popular Dinosaurs Gallery, Birds Gallery, the Cocoon in the Darwin Centre, and the new Treasures Gallery, which opened in November 2012. The Museum also hosts temporary exhibitions, for example the Wildlife Photographer of the Year competition exhibition.

As departments have grown, changed and developed, the education strategy has similarly evolved. A walk around the Museum today still illustrates many different approaches to promoting learning, captured in the historical galleries and contrasting with the more recent additions. For example, the Mineralogy Gallery illustrates the initial ‘index museum’ concept, with specimens grouped according to scientific organisation and taxonomy, often in chronological order with little interpretation apart from scientific names. The Whale Hall, opened in the 1930s, still maintains a taxonomic presentation system, but also illustrates how dioramas were added in some exhibitions to give the specimens some context, along with more detailed interpretation.

The appointment of Roger Miles in 1975 as head of the Department of Public Services marked a significant change in the types of exhibitions in the Museum. Miles was an advocate for, and pioneer in, exhibits that were relatively more interactive than the collections-heavy exhibitions seen before. ‘Human Biology’ opened in 1977 and can still be visited today; it involves very few specimens, rich interpretation and interactive exhibits similar to those now popular in science centres. Miles also encouraged evaluation in exhibition development, for the first time, visitors were asked about their experiences in the Museum with a focus on improving the exhibition and the learning experience of the visitor. The Museum education strategy took a strong lead from the constructivism movement (Hein, 1998) in the development of the ‘Investigate’ Gallery which opened in 2000. ‘Investigate’ places the learner at the centre of their own learning experience and encourages self-motivated discovery rather than a didactic, information transmission approach which was reflected in some of the earlier exhibition interpretation. A constructivist approach continues to influence the education programmes at the Museum and plays a significant role in the training of the science educator staff who interact with the school group visitors and family audiences.

2.5.2 The Darwin Centre

The latest chapter in the Museum's development and education strategy has been the construction of the Darwin Centre, with the second and final phase opening in September 2009. The Darwin Centre with its impressive Cocoon structure (see Figure 1) stores 20 million specimens and provides facilities for 220 scientists to carry out their research. The Darwin Centre hosts interactive exhibits and narratives within the Cocoon about the science undertaken at the Museum. Visitors are able to see into some of the laboratories and the working areas and the Centre also provides opportunities for visitors to talk to scientists.

Figure 1. Views of the Cocoon in the Darwin Centre, Natural History Museum, London (© C.F. Moller Architects/The Natural History Museum, London).

The Darwin Centre represents a new focus for the Museum, aiming to bring visitors closer to the Museum science in the Darwin Centre, to showcase some of the research projects, illustrate the processes of science and engage visitors with the scientists themselves (see Figure 2).

There is an emphasis on social learning in the Darwin Centre, particularly through interaction with scientists and volunteers. The Specimen Preparation Area, for example, allows visitors to speak to scientists working 'on display' within the exhibition. In 2009 the existing Nature Live programme was relocated to the new Attenborough Studio within the Darwin Centre, with new technologies and presentation equipment to aid these discussion events. The development of the Darwin Centre at the Museum is relevant to this PhD research as it marks a major shift in the focus of the public engagement strategy: scientists have become much more heavily involved and visible within the educational programme and exhibitions, and a large-scale evaluation effort was undertaken in which a number of relevant themes were addressed.

Figure 2. Views of scientists in the Darwin Centre, Natural History Museum, London. (Top left – Nature Live, Top right – behind-the-scenes spirit collection tour, Bottom left – views into collections space from the Cocoon, Bottom right – Specimen Preparation Area) (© The Natural History Museum, London).

2.5.3 Opportunities for visitors to meet scientists at the Natural History Museum

There are two regular elements in the Darwin Centre programme which provide visitors the opportunity to interact with scientists: Nature Live sessions and A-level behind-the-scenes days[2]. These two activities were the specific events focused on in this study.

Nature Live events are daily, half-hour sessions, held in the Attenborough Studio within the Darwin Centre of the Natural History Museum, London. Nature Live events aim to provide visitors with an opportunity to meet one of the Museums' scientists, hear more about the scientific work carried out at the Museum, and inspire and encourage discussion and debate around science. Nature Live has been running since 2002 although it has changed over that time. Originally it was called Darwin Centre Live and was hosted in the zoological Spirit Collection Gallery. Events are hosted by one of the Nature Live team, currently five individuals all with a science communication Master's degree, who facilitate the discussion, ask the scientist questions and encourage questions and comments from the audience.

Sessions are made up of a variety of elements and take a number of formats[3]. The host and the scientist will typically have prepared some photographs, diagrams, videos or animations which are shown on the Studio's screens during the presentation. They may have brought along some specimens from the collection for the audience to see and hold or even some things to taste and smell. There may be live video-links to other areas of the Museum or scientists out on fieldwork and the scientist may have brought along some of their fieldwork or research equipment. For example, events have included a mineralogist speaking about what meteorites can tell us about other planets, passing round a sample of Mars rock; another event involved an entomologist discussing the insects that are edible and eaten in other countries around the world, complete with tasting samples.

Nature Live events are considered by Museum staff to be a valuable element of the Museum's educational programme; they are an opportunity for visitors to engage with the scientists who work behind-the-scenes, ask the scientists about their research and see specimens from the

[2] Visitors may also encounter scientists by chance on spirit collection tours as they move about the collection spaces; however these tours are led by science education staff. Similarly, the specimen preparation area is staffed by a scientist at limited times – not for the entire opening hours or everyday, and therefore visitors may not necessarily encounter a scientist in this area.

[3] Examples of filmed Nature Live events can be seen at www.nhm.ac.uk/naturelive.

collections not usually on public display[4]. These events provide an important opportunity for Museum visitors to engage with scientists and are, therefore, an interesting and fruitful research focus to explore public engagement science in museums.

Nature Live events are discussion events similar to those found in many museums, science centres and public engagement organisations. Following the call for more engagement between scientists and publics (UK House of Lords Select Committee on Science and Technology, 2000), many museums and science centres responded by developing dialogue and discussion events (Davies *et al.*, 2009; Lehr *et al.*, 2007). The types of dialogue events seen in these learning environments do not aim to inform policy, as many other dialogue programmes do, but aim to:

> *(1) provide opportunities for empowering individuals for further involvement* [with science]*, (2) be viewed as personally beneficial, or (3) be part of a gradual step by step change in science and society.* (Davies *et al.*, 2009, p. 341)

These aims relate to those of the current research in terms of increasing scientific literacy and engagement with science.

The Museum educational programme offers another opportunity for visitors to meet scientists in addition to Nature Live events in the form of A-level days. Groups of A-level biology students can book to come to the Museum for a day during which they will have a behind-the-scenes session with a scientist in their office, laboratory or collections space, where students can hear about the scientist's research and ask questions. They will then have a special Nature Live event with a different scientist, in a similar format to those described above, again facilitated by a host. After lunch, students take part in a taxonomy workshop and a behind-the-scenes collections tour. These afternoon activities are of less relevance to the current study as they do not involve direct contact with Museum scientists as they are led by science educator staff.

2.5.4 Relevant evaluation conducted at the Darwin Centre

There were three initial aims for the Darwin Centre (Thalund, Pegram, Fitton, Trout, & Sang, 2010):

- To provide state-of-the-art storage for millions of useful specimens;

[4] Only 1% of the Natural History Museum's collection is on public display, the rest remains in storage and collections facilities behind-the-scenes for the use of the researchers.

- To provide new research laboratories for the scientists to study them; and,
- To provide views and insight into this working science facility to the public and educate the public about the science happening at the Museum.

The third aim is the most relevant to this research. The target audience for the Darwin Centre is slightly different to that of the rest of the Museum in that it focuses on adults and students from secondary school and above, rather than family groups and younger students. What follows is a brief discussion of the findings from front-end, formative and summative evaluation from the Darwin Centre development project, and also studies which have explored aspects of the Darwin Centre experience. This discussion provides an overview of what was known about public engagement with science in the Darwin Centre at the start of my doctoral research and illustrates why my research focus is perceived as relevant and useful. Although the Museum has carried out an extensive evaluation of aspects of the Darwin Centre, there had been no research conducted on its impacts on visitors. Furthermore, the findings from the existing evaluations cannot be applied to other contexts and museums as they focused specifically on discrete experiences in the Darwin Centre and were not grounded in theory or literature enabling generalisations to be made to other contexts. In contrast the current study will contribute to knowledge on the Darwin Centre that may be applicable and relevant to other settings and of use to future practice and research beyond the Museum by drawing from theoretical perspectives to understand and interrogate findings.

Although the Museum is a hub of scientific research, 38% of visitors (n = 509) questioned in the baseline survey before the Darwin Centre opened, did not realise that there were *any* scientists based within the Museum (Morris Hargreaves McIntyre, 2009). Along with a lack of knowledge about scientists working in the Museum, those who were aware of their presence had little idea about what they did and used guess work to describe day-to-day tasks (Creative Research, 2005b). Students felt that the work of scientists would be boring and uninspiring and teachers agreed, believing that work would be looking back historically rather than forward-focussing (Creative Research, 2005b). Following the opening of the Darwin Centre there was a significant increase in visitor understanding about the people behind the science at the Museum and the work that those people undertook (Pegram, 2010).

Public perceptions of scientists, as assessed in the front-end evaluation work for the Darwin Centre, were generally positive. There were high levels of public trust in scientists despite some feeling that Museum scientists worked ‘behind closed doors’ (Creative Research, 2005a). Visitors reported that the main appeal to a visit to the Darwin Centre would be meeting and talking to scientists, however this would be dependent on the communication skills and enthusiasm of the individual scientists (Creative Research, 2005b). The scientists themselves were eager to have more feedback on what visitors learn or take from the interactions with them (Thalund *et al.*, 2010).

Dillon, McCallie and Bontrager (2005) studied the first phase of the Darwin Centre, reviewing the ‘Explore’ tour behind-the-scenes in the spirit collection, and the Nature Live sessions. They called for more content around the processes and nature of science in the Explore tours, in contrast to presenting science as established or fixed knowledge, in order to achieve engagement, defined as a ‘two-way process whereby the public and scientists can learn from each other’ (Dillon *et al.*, 2005, p. 5). The live events did not consistently show effective dialogue but varied widely in quality, and more reflexive practice was recommended as well as the involvement of a broader range of trained scientists.

In summary, the Darwin Centre represents a shift in the role of the Museum, bringing together working scientists and public visitors. The Darwin Centre does offer various opportunities for visitors to learn about Museum science, scientists and the processes of scientific research, for example in the Cocoon interactive exhibits, and the concepts and ideas behind the Darwin Centre seem popular and well-received by visitors. These opportunities need further development, however, to provide consistent, interactive, quality learning experiences for a greater number of visitors. Summative evaluations found there is a need for further study to understand the impacts on the visitors taking part in Nature Live events, and how to engage a broader audience in more dialogic interactions (Thalund *et al.*, 2010; Pegram, 2010). The evaluation carried out so far has been fairly simplistic and limited in terms of its application outside the Museum. More detailed research into the impact of the Darwin Centre experiences is needed particularly a greater understanding of what impacts may be occurring which would help to improve the Darwin Centre experience and may lead to further understanding of other museum experiences elsewhere.

2.6 Deciding on a research focus: the Delphi study

As discussed above, this research was carried out as part of a collaborative PhD studentship between King’s College London and the Natural History Museum, London. This collaboration presented a unique opportunity in which to embark upon research and a new set of responsibilities and priorities for the study. Traditionally the focus for a PhD project would be developed and refined through discussions with supervisors and wider academic group, alongside reviewing the literature. Due to the collaborative nature of this PhD, however, it was important for me to involve those working in the Museum in this process of deciding upon the research questions. Many of the staff at the Museum had years of experience in museum education and had been involved in the development of many public engagement activities and exhibitions, including the Darwin Centre in particular. In order to capitalise on the expertise of the practitioner as well as the academic community, I involved Museum staff in the development of my research questions through a consultation process known as a Delphi study.

A Delphi study is a technique used to gather responses from a group of experts, and traditionally involves multiple rounds of surveys and reflection to reach consensus on a particular issue (Abualrob & Daniel, 2013; Linstone & Turoff, 1975; McKenna, 1994). The details of this particular modified[5] Delphi study have been published (see Seakins & Dillon, 2013). Nine staff from the *Science* and the *Public Engagement* groups at the Museum took part in the Delphi study, selected on the basis of their involvement in the development of the public engagement programme and exhibitions in the Darwin Centre. The study involved an initial discussion workshop followed by two email rounds of ranking potential research themes. The modified Delphi process enabled Museum staff to share ideas and priorities for the research study. The multiple aims of this phase of the study were to: 1) arrive at a research focus (and questions) that were a priority for the Museum and of significant academic interest; 2) collate other questions of use, interest and importance to the Museum, which may also be relevant to practitioners and researchers more widely; and, 3) trial a process of identifying these research foci which may be of use in future collaborative projects or PhD studentships.

From the discussion workshop, seven overarching themes emerged, from which research questions and studies could be developed (see Appendix I for full list of themes). These themes encompassed ideas and potential research directions discussed in the workshop. The seven themes were then ranked by the Museum staff involved in order of priorities for a research question and staff were also asked to provide some justification of their choices. Following the first round of ranking, average scores for each of the seven themes were calculated. The average rankings were then circulated to the panel, accompanied by a selection of anonymous statements of justification for each theme. Panel members were asked to rank for a second time, following reflection on the average ranks and the justifications provided. All but one

[5] The method used in Seakins and Dillon (2013) and reported here was modified from the traditional Delphi technique in that it involved a face-to-face element.

panel member changed their ranks in the second iteration compared to the first. The second rankings were collated and averages calculated, resulting in a list of prioritised research themes.

What resulted from the modified Delphi study was not only the prioritised research agenda, including the potential research topic for my PhD, but also an on-going conversation and interest amongst the Museum staff around research. As a result of taking part in the study, staff had a degree of ownership and involvement in the development of the PhD. In conversations with them throughout the studentship it is evident that they have become interested and supportive of the project. My belief in the research area was strengthened – I could be more confident that the specific area I was researching was of interest and value to the Museum. My findings would, therefore, not only contribute to the body of knowledge in academia but would also be of use and importance in practice. The Delphi technique provided a useful tool for integrating academics and practitioners in the development of a research question from the beginning of a project, building on experience, earlier discussions, literature, studies and research agendas in the field, to identify research themes of broader importance.

Following consultation with Museum professionals, and considering the museum learning literature relevant to the context of this research, I identified the topic of my research: *What are the impacts of meeting scientists on visitors to the Museum?* This research, therefore, looks at the impacts of interactions between visitors and scientists, from the visitor's perspective. This topic was a clear preference in both rounds of the Delphi study, ranked by panel members as most important for research to address.

2.7 Conclusions

This section has outlined the broad and specific context of this study. The research is situated within a natural history museum, and as such the literature on learning theory and museum education specifically, was discussed, concluding with the argument that learning is a change in, or strengthening of, attitudes, interest, knowledge, perceptions, understanding or behaviour, compared to before the learning experience.

With the definitions and theoretical basis of learning more clearly outlined, research into the broad and complex impacts of museum visits and out-of-school learning experiences on visitors and learners was reviewed. Of course, not all visitors will experience all possible impacts and some visitors may leave museums without any of the impacts discussed. Each visit is unique, each visitor is individual, and, therefore, the set of impacts for any particular experience will be bespoke and complex (highlighted by Rennie & Johnston, 2004). This is not to say, however, that research into the impacts of museums is not important: research detailing the range of possible impacts for visitors will enable museum staff, educators, visitors and researchers to be aware of the full potential of each experience.

The last section of the chapter turned to the local context for the research: the history and development of the Natural History Museum, a description of relevant programmes, and the Darwin Centre was described as a key turning point in the way the Museum engages its visitors and as the focus for this study. A modified Delphi study was carried out in order to consult the Museum staff about the specific focus for the research, drawing upon their practical expertise in the field. Finally, the research focus identified through this process was presented. In the next chapter, literature from public engagement with science and science education is reviewed to explore what is already known about the impacts of meeting scientists, relevant theoretical perspectives for this research are identified and the refined research question and sub-questions are discussed.

Chapter 3: Perspectives on the roles of scientists in public engagement

3.1 Introduction

In the previous chapter the broad and local context for the current research was discussed, including relevant museum learning theory and impacts of out-of-school learning experiences. The research focus identified through consultation with Museum staff was then described: What are the impacts of meeting scientists on museum visitors? What follows is a discussion of the literature on attitudes towards science and scientists. This chapter provides the context in which I examine how experiences at a natural history museum may influence attitudes and ideas. This chapter draws from the science communication and science education fields, to complement the literature discussed in the previous chapter which was predominantly from the museum studies field. In this way, a more thorough and holistic examination of relevant work can be reached, in a way which supports the study of events such as meeting scientists as part of a learning ecology, in which individuals encounter overlapping experiences such as museums, school, public engagement activities and science as part of their media consumption and everyday lives.

Although the literature from the science education and communication fields predominantly focuses on how to encourage more students to have positive attitudes to science and, therefore, continue to become scientists themselves, my own stance is that of encouraging scientific literacy and engagement with science. I support efforts to encourage informed and positive attitudes towards science with the view that such attitudes may encourage learners to be interested and engaged in science in the future. There is an increasing need for citizens of all ages to engage with scientific information in aspects of their everyday lives and science research will play an increasing role in the decisions citizens must make (Bybee, 1997; Krapp & Prenzel, 2011; Millar & Osborne, 1998). This review will explore the various roles scientists may play in public engagement and how they might influence the development of scientific literacy and engagement. Stemming from the literature, relevant theoretical perspectives will be identified and refined research questions presented.

3.2 Current situation around attitudes to scientists

A number of policy initiatives and research studies have recently been directed at addressing concerns over participation in science, attitudes towards scientists and levels of trust in science research. In 2004 the European Commission declared that ‘Europe needs more scientists’: this phrase was the theme of an international conference in Brussels at which the need to recruit more young people into science was discussed (reported by Gago *et al.*, 2004). In their Seventh Framework Funding Programme the EU also supported ‘Researchers’ Nights’. Researchers’ Nights are large events which take place across European cities in September, bringing together science researchers and members of the public in an attempt to increase awareness around the importance of scientists, the benefits their work brings to society and the diversity within the scientific community, inspiring the public to engage in similar events and scientific careers in the future.

To explore how more young people can be encouraged to pursue science as a career, attention has turned to levels of student achievement and interest in science compared to other subjects. The Organisation for Economic Cooperation and Development (OECD) launched the on-going Programme for International Student Assessment (PISA) study in 1997, comparing student attainment, interest and uptake in reading, mathematics and science across 70 different countries, along with an examination of what influences those attitudes. The same organisation also published a summary of the evolution of student interest in science and technology, addressing concerns about lack of student uptake and declining interest in science (Organisation for Economic Co-operation and Development (OECD) Global Science Forum, 2006). The UK Department for Education and Skills examined the supply and demand for students studying science, technology, engineering and maths in the UK (Department for Education and Skills, 2006). More recently, the focus has spread beyond student populations, with large-scale national studies now looking at the attitudes of adults towards science and scientists, following concerns around a lack of interest and trust in science amongst adults (Ipsos MORI, 2011; 2014).

Despite concerns, the current situation in public attitudes to science and scientists seems to be positive and improving. The latest ‘Public Attitudes to Science Survey’ illustrated some promising changes in public attitudes in the UK. Trust in scientists has increased and people are positive about the potential economic benefits of science (Ipsos MORI, 2014). This trend is supported by other research; trust in scientists was shown as being higher than other sources of scientific information about the environment, such as environmental organisations or the news media (Brewer & Ley, 2013). Public interest in science has increased and most people believe that the benefits from science are greater than any harmful effects and that science makes people's lives easier (Ipsos MORI, 2011; 2014). Some researchers have even commented that science may be seen as becoming 'cool' (Dillon, 2011). The current situation in the US mirrors that in the UK. Adults completing the National Science Foundation *Surveys of Public Understanding of Science and Technology* were more positive about scientists and more likely to endorse a career in science in 2001 compared to those surveyed in 1983 (Losh, 2010). However, attitudes towards science are not all positive; people are still concerned about the reporting of science and do not feel well informed about science – the numbers of people in the UK feeling informed about science in 2014 remain below 2008 levels (Ipsos MORI, 2011; 2014). This last trend highlights the need for continued and improved initiatives in science engagement if we wish for the public to feel able, prepared and interested to find out more about science. By increasing motivation in science individuals may feel more informed and confident in the decisions they face relating to science and technology in the future.

Recent studies provide a closer look at what exactly the public feels about science. For example, findings from a study conducted in the Natural History Museum, London, provides clear insights into families' perceptions of science. When asked what they thought about science, common answers included that science was a type of activity or endeavour that involves processes and observation, science raises new questions, is 'facts' or knowledge and is defined by its content (DeWitt, 2013). Visitors spoke about science as something separate from other experiences that were interesting, child-friendly, hands-on and educational. Recent studies with students give similar cause for concern. Students in the Netherlands saw science as uninteresting, too demanding, difficult, too much technology or theory driven and too narrowly focused (Korpershoek, Kuyper, Bosker, & van der Werf, 2012). In the UK, students were surveyed about their attitudes towards science and the findings were reported in a paper titled 'Would you want to talk to a scientist at a party?' (Bennett & Hogarth, 2009). This title is taken from the responses of one of the students participating in the study, whose rhetorical question reflects the findings that many students thought science was important but not personally appealing or interesting. Bennett and Hogarth's findings provide rationale for the current study and reflect one of the main issues currently facing the field of public engagement with science and science education: attitudes to science are, on the whole, positive, but the public do not feel inspired, interested or motivated by science. Indeed, science is seen as something separate and removed from everyday life.

The current state of attitudes towards science is complex. In response to previously negative attitudes towards science, there has been an increase in science communication initiatives, aimed at engaging non-scientists in science activities to increase positive attitudes and interest in science. As Dillon has observed:

> *If the UK is not the home of science communication, it is a place where science communication, surely, feels at home. That is not to say, however, that science itself is unconditionally appreciated or that scientists are universally trusted.* (Dillon, 2011, p. 5)

In the next section I explore the extent and range of science communication through discussing the various roles scientists might play in public engagement.

3.3 The multiple roles of scientists in public engagement

The role of scientists is primarily to carry out research and advance the field of scientific knowledge. However, scientists are also increasingly involved in public engagement activities, and come into contact with those outside their research groups and networks. Some argue that the increasing pressure on scientists to communicate their research and take part in public engagement activities may in fact discourage some scientists from pursuing their research further (Bischofberger & Guarnera, 2010). This argument leads to dilemmas around how much emphasis should be placed on scientists' involvement in public engagement activities. By understanding more about what impacts scientists may or may not have, the current research aims to add evidence to the debate over whether time spent on public engagement is justified.

Scientists may have a number of outward-facing roles alongside carrying out their actual research. What are the different roles scientists might play in public engagement activities and what influence might such roles have on those with whom they are interacting? Why might it be beneficial to involve scientists in public engagement? And why might it be preferable for scientists themselves to be involved rather than science educators? The following review explores the literature relating to the roles scientists play in public engagement, clarifying what types of impacts might be expected from interactions between scientists and visitors to the Natural History Museum, London.

3.3.1 Influencing attitudes to scientists and science

Scientists have a role as the 'face of science', influencing attitudes to science research and towards those working in the field. Their role here might be seen in the sense of 'advertising': scientists involved in public engagement are representatives or the 'faces' of the science community for their audience. Their actions, roles and behaviours, therefore, will reflect on both the particular science discipline and on other scientists, and influence public attitudes towards the scientific field.

i) Why attitudes are important

A word used frequently but rarely defined, 'attitude' has meaning for most people as the feelings towards a particular object, and can be positive or negative in nature. 'Attitudes towards science' encompasses views about a broad range of constructs. Bennett (2003) describes the elements making up attitudes to science as including dispositions to the following: school science, science outside school, the relevance and importance of science to everyday life, scientists and scientific careers. In Osborne *et al.*'s (2003) review of the literature on attitudes to science, they develop a definition which includes the enjoyment of science learning experiences, development of interest in science and science careers, and an understanding and development of science inquiry skills in their definition of science attitudes.

As defined above, interest is a key aspect of attitudes to science (Osborne *et al.*, 2003). Researchers focusing on interest have stressed its importance for motivation in learning (Krapp & Prenzel, 2011). Interest prompts a content-specific intrinsic motivation to engage – no external motivations such as payment or qualifications are present (Baram-Tsabari & Kaadni, 2009; Krapp, 2002). Developing interest as a result of a learning experience may encourage future engagement and enjoyment, and could even be linked to intentions for future career choices (Ainley & Ainley, 2011a). Interest as a theoretical perspective for this work is discussed further in section 3.4.2.

Research into attitudes to science stretches back to the early 20th century and has focused mainly on the attitudes of children and students, to school science in particular. Early studies identified groups of attitudes (for example Miller, 1983), and subsequent large-scale surveys studied the attitudes of large groups of individuals, often internationally (Ogawa, 2011). Critiques of previous work into attitudes to science have emerged, criticising the lack of theoretical grounding in psychological theory; poor instrument design; poor data analysis strategies; a tendency to repeatedly design new instruments without learning from previous studies; and a lack validity and reliability measures (Bennett & Hogarth, 2009; Blalock *et al.*, 2008; Osborne *et al.*, 2003). A further criticism, particularly of earlier quantitative work, is that attitude measures have predominantly relied on scales and fixed response data which reflect the views and perceptions of the researchers and instrument developers rather than the respondents themselves (Bennett & Hogarth, 2009). I agree with this critique of some quantitative work in that it can provide limited findings which are biased by the researchers' agendas and perspectives. For this reason, I take a predominantly qualitative approach in this work and analyse the data in an iterative 'bottom-up' way, allowing the responses of participants to form the analytic framework.

ii) Science in school and student attitudes to science

The majority of the research into attitudes to science started with, and has continued to focus on, school students. Attitudes towards school science, that is the science lessons, activities and information students experience within school, have been studied widely, and began with the work of Mead and Metraux (1957). This seminal work analysed US high school students' essays and summarised their attitudes to science and scientists. The findings highlighted that although students were positive about science overall, including its role in society and driving progress in the world, on a personal level the students were not interested in science and held stereotypical views of scientists.

Over 50 years on from Mead and Metraux's 1957 paper, attitudes to school science remain similar. Students, aged 15, surveyed in the Relevance of Science Education (ROSE) comparative study, indicated that they thought science was interesting, relevant and important, but that they did not aspire to work in science themselves in the future (Jenkins & Nelson, 2005). Students in other studies indicated that they found science outside school more interesting than the science they learned about in their lessons (Bennett & Hogarth, 2009). Even amongst those students pursuing science in further study there was a feeling that the science taught in school lacks relevance to students' everyday lives (Cleaves, 2005).

Bennett expands on the idea of relevance in her writing on context-based approaches to science education (Bennett, 2003; Bennett, Lubben, & Hogarth, 2007). The key to context-based approaches is that the scientific principles are introduced after the familiar everyday context, with the links between science and the lives of the students used as the starting point for learning more. The perceived relevance and accessibility of science is important in shaping science attitudes. For example, promoting the relevance of science has also been explored in order to encourage student engagement with school work (Assor, Kaplan & Roth, 2002; Logan & Skamp, 2013). Bridging the gap between school science, science research and students' everyday lives may increase positive attitudes. Rennie (2011) suggests making school science more explicitly accessible so that students know how to access more information and appreciate science as a human endeavour, rather than a remote body of information often difficult to understand. These types of approaches to science education have been shown to increase interest and enjoyment in science learning, enabling students to see clear links between their own lives and the scientific concepts (Bennett, 2003). In addition, researchers suggest that interactions with scientists in an open and accessible format, such as a science café, may lead students to see science as more engaging and relevant to their own lives (Hall, Foutz, & Mayhew, 2012; Mayhew & Hall, 2012).

Teachers may play important roles in shaping student attitudes to science (Osborne *et al.*, 2003) and, therefore, research has explored the attitudes of science teachers themselves. A study looking at the effects of a summer research programme for teachers found that they developed a sense of membership in the community of science, increased confidence, increased ownership of their work and a more developed understanding of scientific inquiry as a result of being mentored by science researchers on the programme (Hughes, Molyneaux, & Dixon, 2012). The degree of the impacts on teachers varied according to the approach and involvement of the mentors, which in turn influenced how teachers translated their new understandings and attitudes to their work in the classroom.

iii) Influences on attitudes

The role of teachers and the experience of school science may be one factor influencing the formation and development of attitudes towards science. However, there are a suite of other factors which have an impact on how students and adults see and feel towards science, including attitudes of peers, family and teachers, students' perception of the science teacher, achievement and failure in science, and the nature of the classroom environment (reviewed in Osborne *et al.*, 2003). A number of these influencing factors are discussed below.

Research has explored the influences on science attitudes stemming from life outside school, with a particular focus on the role of families and family members. For example the ASPIRES project – an ESRC-funded longitudinal study focusing on science aspirations and career choices of students aged 10-14 has looked at the influence of family attitudes towards science, specifically those of parents, in shaping children's attitudes. Findings indicate that parents play an important part in the development of children's feelings towards science and that families with higher science capital – including qualifications in science, knowledge, interest and social contacts that are related to science – are more likely to encourage positive attitudes in their children (Archer *et al.*, 2012b; Archer *et al.* 2013b, Bourdieu, 1977). When taking part in public engagement, therefore, scientists have impacts not only on the adults they may interact with directly, but indirectly on the children of those adults, who may be influenced by the attitudes of their parents and other family members.

A concern over the imbalance of males and females pursuing careers in science has led researchers to study gender differences in attitudes to science more closely. Differences between male and female attitudes have been identified and explored. Findings from the ROSE study with 15-year-olds indicated that biology was more appealing to girls than boys, boys wanted to know more about destructive technology and events, whereas girls were more interested in health and well-being (Jenkins & Nelson, 2005). Girls were also more sceptical and negative about science in general (Sjøberg & Schreiner, 2010). Girls were more likely to disagree with statements such as 'school science is rather easy for me to learn', were less likely to say they like school science better than other subjects and were less likely to aspire to a job in technology (Jenkins & Nelson, 2005).

Science attitudes have been shown to vary between different countries. A large-scale survey of attitudes of the UK public makes comparisons between the attitudes of the UK public and those in other European countries (Ipsos MORI, 2011). For example Eastern European respondents were more likely to include broader subjects such as social science, economics, psychology as being part of science, as they felt that these subjects used the scientific method, whereas the UK public had a more narrow definition of what science is (Ipsos MORI, 2011). Clearly international differences exist in science understanding and in terms of how science exists alongside culture. The roles of scientists will, therefore, vary across countries in terms of the purpose of, reception to, and potential impacts of their science engagement efforts.

3.3.2 Stereotypes and images of scientists

If scientists taking part in public engagement are representatives of the community of science, they also have a role in competing with other images of scientists and representations elsewhere, in particular stereotypical images in the media. Scientists, therefore, potentially confirm or challenge previously held stereotypes and depictions of scientific researchers encountered elsewhere.

Perceptions of scientists are linked to attitudes to science; images of scientists play a role in shaping attitudes towards science careers and notions of self-efficacy in science (Finson, 2002). Research into attitudes towards, and images of, scientists, began with work by Mead and Metraux (1957), mentioned above, who asked students to write essays describing their images of a scientist. Stereotypical images emerged within the students' essays, including male scientists, crazy hair, beards, glasses and white lab coats, which are now recognised as the 'classic' stereotype image of a scientist. A significant literature base has been established looking at perceptions of scientists, with an abundance of measurements, scales and tools for exploring images of scientists. In the following section, literature on images of scientists is discussed, beginning with stereotypes of scientists and then discussing influencing images of scientists.

i) Stereotypical images of scientists

A persistent stereotype of scientists exists similar to that described by the students in Mead and Metraux's seminal work (1957). Stereotypes, and in particular physical attributes, have been studied further using Draw-a-Scientist tests, starting with Chambers' study (1983). Drawings were gathered from 4,807 children aged 9-10, which indicated some clear stereotypical perceptions of scientists held by the children. Firstly, only 28 females were drawn from the total of 4807, demonstrating a significant gender imbalance in children's images of scientists. Seven further items appeared frequently in the children's drawings (reviewed by Finson, 2002):

- Lab coat – usually white;
- Facial hair;
- Glasses;
- Symbols of research – for example instruments and laboratory equipment;
- Symbols of knowledge – for example books, filing cabinets;
- Technology – for example products of science such as rockets;
- Captions or words – for example 'eureka!', formulae.

The features above can be described as the traditional stereotypical features of scientists. Additional features were added later to include alternative stereotypical features: scientists being white; indications of danger included within drawings; light bulbs; images which suggest secrecy; scientists being old; working indoors; and fictional creatures such as Frankenstein's monster (Finson, 2002; Finson, Beaver, & Cramond, 1995). Even with the updated features, the overall stereotype of scientist seems negative; it is difficult to imagine that this would be an attractive image for young people to aspire to for their future careers.

Draw-a-Scientist tests mostly uncover physical perceptions of scientists: students are more likely to draw what they think scientists will look like – personality traits, mannerisms or habits are harder to draw. However, other surveys have explored perceptions of scientists further, beyond physical appearance. Losh (2010) looked at five such stereotypes about scientists and the changes in perceptions of these over time, by comparing National Science Foundation 'Surveys of Public Understanding of Science and Technology' responses from 1983 and 2001. The five items were:

- Scientists have few other interests besides their work;
- Scientists don't get as much fun out of life as other people do;
- Scientists are apt to be odd and peculiar people;
- Scientists are not likely to be religious people;
- Scientific work is dangerous.

Adults surveyed in 2001 were more positive about scientists in relation to all items compared to 1983, although over half of those surveyed in 2001 still believed that science was dangerous and one quarter still thought scientists were odd and peculiar (Losh, 2010). There are, therefore, some persisting stereotypical ideas about the personality of scientists as well as their physical appearance.

The study by Losh (2010) is unusual because it looks at the perceptions of adults, rather than children, to scientists. In this way, Losh's study is a particularly important work for this thesis – not only does it focus on broader non-physical perceptions of scientists, but also on perceptions of adults rather than children. The majority of studies using the Draw-a-Scientist test have examined perceptions of children, as the drawing task is a useful tool to use with younger children who may not be able to express themselves as easily verbally. Aside from work with teachers, images of scientists and stereotypes held by the general adult population have been relatively understudied compared to students and children (Finson, 2002; Losh, 2010). However, recent surveys of the UK population have looked at perceptions of scientists amongst adults. These extensive surveys revealed that adults think of scientists in very stereotypical ways, largely thinking of them as men working in laboratories (Ipsos MORI, 2011). Interestingly 50% of those surveyed thought that scientists are secretive, and 40% considered scientists to be poor communicators (Ipsos MORI, 2014).

Some stereotypical views of scientists, therefore, seem to be relatively persistent over time. The stereotypes held by students in different countries have also been compared to see how persistent perceptions are across international borders. Overall, stereotypical images of scientists seem to be largely persistent and pervasive across grade, racial groups, national borders and gender (Finson, 2002). Studies from various countries indicate that there may be areas in which perceptions are changing and becoming more positive, for example students in Spain saw scientists as less dangerous than in previous studies (Rodari, 2007; Ruiz-Mallén & Escalas, 2012).

In considering how ideas and perceptions are developed and influenced, theories of stereotype formation are relevant. Stereotypes exaggerate between-group differences and underestimate within-group differences. Stereotypes of scientists, therefore, overlook variation within scientists as a group of individuals and instead focus on differences between scientists and non-scientists (DeLamater & Myers, 2007). People who stereotype scientists see themselves as further away from scientists in terms of psychological distance, compared to individuals who do not hold stereotypical images (Losh, 2010). This idea is also relevant when thinking about how to encourage students to picture themselves as scientists; if students hold stereotypical images they are less likely to match their own identity with that of the scientist, achieving ‘self-to-prototype matching’ (Taconis & Kessels, 2009). Self-to-prototype matching involves students considering how closely aligned their own identity is to a prototype or ‘typical’ science student, and how similar they perceive themselves to be compared to others with science identities. Scientists, therefore, have an important role in portraying realistic and diverse images of individuals in science which may challenge traditional, narrow stereotypes.

ii) Influencing images of scientists

Concerns over perceptions of scientists has led to research aimed at understanding how images of scientists can be influenced to be more realistic, positive and representative of the science community (for example Christidou, Hatzinikita & Samaras, 2012). Researchers have recommended that scientists and the scientific research community become more involved in the promotion of the field and its people, thinking about how the images of science are portrayed and encouraging young scientists to take part in the future (Christidou, 2010). For example, the ‘Observatory of Study’ programme in Barcelona encourages students to meet scientists based on a premise that exposure to individuals who are active in research will enable students to form more accurate images of scientists (Ruiz-Mallén & Escalas, 2012). The current research explores further the impacts meeting scientists has on developing broader and more realistic perceptions of scientists.

Interventions involving direct contact between students and scientists seem to yield promising impacts on perceptions of scientists. In one intervention, students who experienced a programme where they visited research labs and met scientists, had visits by scientists into school and took part in discussions about lives of individual scientists from history and the present day, demonstrated more accurate and positive images of scientists in drawings compared to a control group (Cakmakci *et al.*, 2011). Specific changes in students' drawings of scientists following this intervention included more female scientists, fewer wearing glasses and lab coats and more indication that scientists were 'people like us' (Cakmakci *et al.*, 2011). Similarly, students taking part in a week-long nanotechnology programme in which they interacted with scientists developed broader ideas about the diverse careers, roles and locations available in science (Painter, Jones, Tretter & Kubasko, 2006). These findings suggest that direct interaction with scientists can have positive impacts on perceptions of scientists.

Further impacts on perceptions of scientists were seen through studying a 'side-by-side' programme, where middle-school girls worked alongside scientists for five days (Farland-Smith, 2009). Girls worked in the scientists' research environments and took part in projects and discussions with the scientists. The study demonstrated that the 'side-by-side' programme experience led the girls to have more expansive views of scientists, broader ideas about their appearance, location of work and the activity scientists take part in day-to-day (Farland-Smith, 2009). The programme seemed to have no effect on students' attitude towards science itself; the girls were already positive about science and, therefore, their attitudes were not changed as a result of the activities. The fact that the 'side-by-side' programme had impacts on perceptions of scientists but not attitudes to science has implications in thinking about how interventions are studied in the future, what is measured and what impacts are targeted. These findings indicate where using some measures, for example studying attitudes to science only, may result in other impacts, for example perceptions of scientists, being overlooked. In an attempt to ensure that this thesis does not replicate the same limitations, the approach to data collection for the current research has been open and broad – ensuring that the interview schedules, for example, address a range of topics and have opportunity for new and different themes to be covered.

Internship programmes partnering students with research scientists have had similar positive impacts on students' perceptions of scientists and careers in science. For example, structured pre- and post-interviews were carried out with students participating in a two-month internship programme in which they spent around 18 hours in a laboratory with graduate students working in science. Findings indicated that the experience enabled students to see scientists as real, ordinary people and that it was not necessary to be a genius to be a scientist (Roth, van Eijck, Hsu, Marshall, & Mazumder, 2009). Another internship demonstrated positive impacts on female students' ideas about scientists and working in science, impacting their career plans over time and their perceptions of themselves as future scientists (Packard & Nguyen, 2003). The mentoring relationships girls had with their supervisors within the lab were particularly important in affecting the students' perceptions of themselves as future scientists. Scientists, therefore, have a key role in potentially influencing perceptions of science, scientists and science careers through face-to-face interactions with different publics. These positive effects were not true for all students however – the aboriginal students participating in the internship programme described by Roth et al. were discouraged from pursuing science careers, as they encountered ideas during their experience that clashed with their own cultural views on the environment. This finding reiterates that not all internship programmes, public engagement activities or scientist role models will lead to positive impacts for every student, learner or visitor. Presenting scientists as role models can lead students to either identify more closely with science, or see that it is not for them and retract from science further. Caution must be used, therefore, when designing, implementing and researching these types of programmes.

iii) Images of scientists research

The Draw-a-Scientist test has been used and developed in much research into images of scientists, and has been the focus of methodological discussion as to whether it is the most valid way to explore perceptions. As discussed earlier, use of drawing over other oral or written communication is likely to elicit more physical features as opposed to personality traits or habits of scientists. While a useful tool to use with people who may not be able to articulate their thoughts in an oral or written way, an over-reliance on the Draw-a-Scientist test has led to research being focused on physical appearance of scientists for many years.

The Draw-a-Scientist test often utilises a scoring system whereby each picture is scored according to how many stereotypical features it includes. This scoring method was used in a study by Laubach, Crofford & Marek (2012). When interpreting drawings, however, it should be remembered that a low score does not necessarily mean that an individual has a realistic or non-stereotypical view of a scientist – individuals may have a less informed or detailed perception of scientists and, therefore, were unable to draw a complex image with many features. This limitation is discussed alongside other issues of the Draw-a-Scientist test in a critique by Losh, Wilke and Pop (2008). Within research into perceptions of scientists there is an overemphasis on examining negative stereotypical features, for example scientists being dangerous or old, without a comparable focus on positive stereotypes, such as scientists being intelligent and independent (Losh *et al.*, 2008). In the current study, scoring was not carried out for stereotypical features only; the frequency of all descriptors was used in comparing participants' expectations and experiences of scientists. This study, therefore, takes a more balanced approach to studying perceptions of scientists than studies using Draw-a-Scientist tests.

Furthermore, phrasing of the task 'Please draw a scientist', or similar, is likely to elicit drawings of a single individual and, therefore, is less likely to pick up on perceptions of scientists as sociable people who work with others (Christidou *et al.*, 2012). Even if students have multiple images of scientists, when asked to draw only one they may be likely to draw the image they feel is expected from the researcher and, therefore, the stereotypical image (Finson, 2002; Jenkins & Nelson, 2005). The enhanced Draw-a-Scientist test included modifications to enable students to draw more than one scientist and included additional questions to enable students to elaborate on their drawings. The enhanced Draw-a-Scientist test has been used in exploring the attitudes of girls towards scientists (Farland-Smith, 2009). Participants are still asked, however, to focus on one image of a scientist per page, which may still be likely to encourage a focus in on stereotypical features. Research asking pupils and trainee teachers to draw two scientists, however, enabled multiple perceptions of scientists to be explored (Matthews, 1996). This work revealed less gender bias in the images of scientists compared to previous studies, although scientists were still predominantly drawn in a laboratory setting, suggesting that students held multiple images of scientists, some of which remained to be stereotypical (Matthews, 1996).

3.3.3 Scientists as inspiration or role models for future careers

The idea that scientists may play a role in inspiring students to choose future careers in science is often the rationale for studies into attitudes towards and images of, scientists. Scientists taking part in public engagement are examples of those working in a science career and, therefore, are a reference or model to compare oneself to when considering what a career in science might be like. Although the aim of the current research does not specifically relate to encouraging students to pursue careers in science, much of the relevant work on perceptions and roles of scientists has been carried out with the aim of increasing uptake in science fields. This literature is relevant to the current study in that it explores how scientists can act as role models and impact the perceptions and science identities of others.

i) Science role models

Research suggests that students are more likely to select a career when they can identify a role model within that career (Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008). Two hypotheses of how and why role models might influence career choices have been proposed; the Role Model Hypothesis which predicts that same sex individuals will be most influential as role models as gender is crucial to the process of identification with others; and the Opportunity Structure Model, which predicts that those who can communicate their knowledge most effectively and have higher educational backgrounds will be most influential (original model proposed by Betz & O'Connell, 1992; Sonnert, 2009). A study with a sample of US scientists, exploring the factors that inspired them to take part in a science career indicated that the Opportunity Structure model was more appropriate: scientists were more likely to cite parents and individuals with higher educational achievement as their inspiration (Sonnert, 2009). The role models cited by scientists were not necessarily of the same gender, therefore challenging the Role Model Hypothesis.

Interactions with other people shape students' perceptions of whether they are 'science people', particularly whether they are considered by others to be sufficiently interested, suitable and skilled for further science education (Sjaastad, 2012b). Significant persons or role models may act as definers or models, as described the in the Significant Person Theory of Woelfel and Haller (1971). Definers are people who communicate norms through their expectations and language towards individuals, therefore their influence on science identity development is communicated directly through words (Sjaastad, 2012a). Models, on the other hand, lead by example, they provide information about the norms of the role, in this case science careers, which then influences the attitudes of the students and provides points of reference (Sjaastad, 2012a). In the current research, scientists may act as models, examples of what someone who works in science might be like; and other adults with whom an individual may have more sustained, regular and personal contact, for example family members and friends may act as definers, reinforcing science identities through their interactions.

Initiatives in science education have attempted to introduce science role models to students in a number of different ways. A programme from the US introduced frequent visits from graduate scientists into schools, with less frequent visits from other diverse scientists from the community, alongside activities in the classroom researching famous science figures, to provide role models for girls in science (Buck *et al.*, 2008). The researchers asked female students what they thought role models were, what it meant to them for someone to be their role model and in what ways scientists could be role models. The girls defined a role model as 'someone with whom they feel a deep connection'; girls gave examples of role models from their family of people who care about them (Buck *et al.*, 2008). The girls spoke about how stereotypical images of scientists contrasted with the characteristics of other role models; girls felt that scientists were too clever to be connected to and care about them. By the end of the six-month programme, however, participants had changed their earlier ideals that scientists could not be role models and felt that in fact an ideal science role model might be someone who has a good personality, expertise in science and was able to make personal connections (Buck *et al.*, 2008). The work of Buck *et al.* is significant for the current work in that it explores how individuals may identify more closely with scientists, and examines the characteristics which make closer identification more likely. Whilst the focus of Buck *et al.*'s research was a six month programme, I explore how a short-term interaction may facilitate similar identification with scientists.

As in the study, detailed above, by Buck *et al*. (2008), research into science role models has often focussed on girls and their choices into whether to go into a scientific career. Such research follows the idea that the stereotypical image of a scientist is most often male, first reported by Mead and Metraux (1957). It is thought that perceptions of scientists clash with perceptions of future selves in girls and, therefore, they do not choose to pursue science further (Buck *et al.*, 2008). Although role models are important for both sexes, research has concentrated on girls in an effort to encourage more girls to enter scientific careers. In order for students to take on a science identity, there needs to be some aspects of science which fit the other elements of their existing identities. It is suggested that this match is harder for girls than for boys, as girls' identities clash with the masculine characteristics of hard, rigid, objective science (Hughes, 2001). Through the provision of role models or other initiatives, therefore, girls can be given opportunities to see how science identities can fit alongside aspects of their own identities (Hughes, 2001). In a study into girls who were already keen on taking up science careers, Archer *et al.* (2012a) explored the strategies girls were using to match their own identities with that of a future scientist. Two narrow identity constructs were identified by girls when navigating the ideas that science is masculine and clever; they either adopted a sexualised science femininity, which overplayed 'girly-ness' perhaps to compensate for their interest in science; or they took on an asexualised 'bluestocking' scientist which linked the hard-working and studious aspects of the girl's existing identity with science.

Research into science role models, therefore, presents some interesting implications for future work and study in the area. The findings from Buck *et al.* (2008) suggest that the only impactful way to initiate role model relationships is through face-to-face interaction – it was important for the girls in the study to have a personal connection with their role models, engaging in conversations and knowing about one another. In contrast, video representations of scientists had little impact and were not mentioned by the girls when talking about role models. Gibson (2004) argues for role models to represent a range and diversity of different scientists, of different quality and characteristics, rather than presenting 'ideals'. Events such as Nature Live at the Natural History Museum are one way in which many different scientists can become involved in public engagement, therefore presenting a diversity of individuals as potential models.

Provision of appropriate role models cannot single-handedly encourage students to embark on science education and future careers. Role models may address barriers preventing students imagining themselves on a science career path, but may not address issues of attainment and achievement necessary to gain the relevant qualifications required to take a science degree, for example. Understanding and appreciating of the nature of science, therefore, alongside considering issues of interest and motivation in conjunction with providing suitable role models are all important when seeking to encourage positive attitudes towards careers in science.

ii) Attitudes to science careers

Whereas attitudes to science as a subject were explored above, this section focuses on attitudes to science careers specifically. A substantial proportion of the research into attitudes to science has focused on attitudes to science careers and science. Various reasons have been proposed for the decline in students choosing careers in science during 1990s and 2000s, including that pupils have a skewed image of the nature of science and the work that scientists undertake (Cleaves, 2005). The discussion above on the literature on attitudes to science and perceptions of scientists, therefore, is relevant and connected to attitudes towards science careers.

The link between attitudes to science and attitudes to science careers has been explored in the ASPIRES research; findings indicate that students see a difference between 'doing science' and 'being a scientist' (Archer *et al.*, 2010). Through surveys and interviews it was found that most children enjoyed doing science activities, but did not want to continue on to study science and become a scientist. Students saw science as important, but were unlikely to want a career in science themselves; 60% of 16-year-olds agreed with the statement 'it is important for this country to have well-qualified scientists', whereas only 14% agreed that 'it would be good to have a job as a scientist' (Archer *et al.*, 2010). Students felt that science was hard and that scientists needed to be brainy and have a natural ability or interest in science.

Attitudes to science careers seem to be improving, perhaps due to the expansion of initiatives targeting science career-specific attitudes. In a recent survey of the UK population the proportion of adults in 2014 stating that science careers are interesting rose to 73%, compared to 68% in 2011 (Ipsos MORI, 2011; 2014). In a comparative study in the US carried out by Losh (2010), the number of adults saying that they had considered a science career themselves rose from 35% in 1983 to 45% in 2001, whereas the number saying they would be happy if a son or daughter wanted a career in science rose from 67% in 1983 to 80% in 2001. Careers in science, therefore, seem to be increasingly attractive to individuals, as options for themselves and for others.

If more students are encouraged to pursue careers in science, eventually a dilemma arises in terms of supply and demand. Some researchers have argued against the idea that the UK needs more scientists (Smith & Gorard, 2011), stating that it is unethical to channel such effort into persuading students to embark on science courses if at the end of their study there are insufficient numbers of jobs for them. The team behind the ASPIRES project raise an interesting question: what proportion of students *should* be inspired to study and work in science at an early age, to ensure a balance between supply and demand for scientific jobs? And, therefore, what should the science education and communication communities be aiming for when targeting students with these initiatives (DeWitt *et al.*, 2013)?

Further to the provision of role models in science, there are a number of other factors which influence whether or not a student would choose to pursue a career in science. These influences are reviewed by Cleaves (2005), who interviewed students over three years about their formation of science career choices post-16. Four factors were confirmed to influence the decision to carry on with science education:

- Self-perception with respect to science;

- Occupational images of working scientists;
- Relationship with significant adults;
- Perceptions of school science.

Similar findings have been reported in studies with younger children, where attitudes towards science careers are linked to attitudes to school science, self-concept in science and parental attitudes towards science careers (DeWitt *et al.*, 2013).

Parental attitudes to science have been confirmed to be important for students' attitudes to science careers; parents are key parts of the social communities students operate within (DeWitt *et al.*, 2013). These 'micro-communities' within and outside of school – those people the student speaks to on a regular basis – are indicated to be influential in attitudes to careers and affect decision-making (Aschbacher, Li, & Roth, 2010).

From the PISA study data, the relationship between science knowledge, affect and value in science as components for interest in science has been studied (Ainley & Ainley, 2011a). These measures of interest in science are used as predictors of future behaviour and participation in science related activities, including future careers. Interest in science particularly at age 16 seems to be a strong predictor for a commitment to the subject in the long-term (Smith & Cooke, 2011). An interest from the age of 13-14 in science careers specifically is also an indicator of long-term science career interest – half of students interested in science careers at this age followed through with their science career choices and achieved degrees in a science-related field (Tai, Qi Liu, Maltese, & Fan, 2006). Inspiring interest early and nurturing interest in the subject of science, therefore, is an important factor in developing interest in science careers. The current study, however, does not focus on the impacts of meeting scientists on science career plans and instead explores whether such interactions have impacts on other interests in older students and adults.

Without a clear and realistic understanding of what is involved in a career in science, students are unlikely to form strong attitudes about it, be they positive or negative. A study which looked at case studies of students making their science career choices concluded that those students who were aware of the breadth of science careers, who had an open mind about science, who had a realistic picture of scientists, and who were less likely to stereotype scientists, were more likely to choose science as an option for themselves (Cleaves, 2005). Out-of-school learning experiences provide many ways to increase student awareness of the diversity of career options in science, through museum programmes, online articles, laboratory visits and internships for example.

Further research has confirmed that participation in out-of-school science activities such as clubs and competitions, reading about science and watching science programmes was linked to students being more likely to be interested in science careers at university (Dabney *et al.*, 2011). Whilst this is promising and supports the conclusions from earlier studies, the study by Dabney *et al.* is a retrospective one and, therefore, cause and effect relationships cannot be claimed. It may be the case that students were interested in science from a very young age and took part in related activities, which only confirmed their preferred career direction. This study illustrates the difficulty in researching triggers and influences of career decisions; such research requires long-term studies over a number of decades and that identifying triggers and key factors contributing to decision-making and attitude formation is complex. Instead, I would argue that a perspective of a learning ecology is useful here –the acknowledgement of influencing factors and experiences as incremental and interlinked within a diverse, broad, dynamic and long-term landscape, which affect attitudes and knowledge throughout a person's life. Learning ecologies are discussed further in section 2.2.3.

A relevant study into out-of-school science activities, used extensively in the current research, looked at the questions asked to scientists by students (aged 16-18) who met two research scientists as part of a laboratory visit (France & Bay, 2010). Questions were categorised and used as indicators of interest of the students, and interviews probed further impacts of the experience on the students. As a result of their experiences in the laboratory and interactions with scientists, students became interested in the scientists on a personal level, made connections to the scientist and developed broader understandings of the process of science. This thesis adopts ideas from France and Bay's study in that it also analyses topics of questions as indicators of interest and explores how face-to-face interactions may facilitate identification with scientists.

Increasing awareness of the diversity of careers in science, the diversity of people in science and breaking down stereotypes in science may, therefore, enable more students to identify with science careers. Integrated information about science, the context of science and career opportunities in science need to be provided for students to see clear, diverse, varied and valuable roles within science (Bennett & Hogarth, 2009). Scientists, therefore, have a role to communicate not only their scientific research, but also the context of their work, their contributions to society and information about their role and job, in order to increase positive attitudes towards science and science careers.

3.3.4 Scientists as experts

Scientists often adopt the role of an expert, due to their high level of knowledge in the field of science and their perceived high status. Many public engagement events involving scientists include some sort of presentation or lecture on the scientist's own topic of expertise; the audience come to hear about the subject from the scientist who is particularly knowledgeable about it. There are many initiatives which highlight the expertise of scientists in relation to the publics they interact with, for example 'Ask-a-Scientist' websites provide a forum for students and members of the public to ask scientists questions and receive answers. Ask-a-Scientist sites have been studied to explore student interest and questioning; the questions asked to the scientists indicate the areas children are keen to know more about (for example Baram-Tsabari, Sethi, Bry, & Yarden, 2006). Often the only contribution from audience members at large public engagement events such as lectures is questions, which may serve to exacerbate self perceptions of inferiority with respect to science understanding. In contrast the scientists are presented as holders of information, which in turn confirms their expert status.

A new phase of dialogue events and initiatives has attempted to change the standard format of a scientist giving a presentation and audience members asking questions afterwards. Two-way communication between scientists and non-scientists was called for following concerns that the deficit model of one-way science communication was not leading to positive impacts on public attitude to science and perceptions of scientists (UK House of Lords Select Committee on Science and Technology, 2000). Dialogue events were originally designed to engage publics in decisions about science policy, however dialogue events are now used for many other purposes and their value as a form of public engagement in their own right has been recognised (Davies *et al.*, 2009). As such, dialogue events have become increasingly popular, attempting to deconstruct traditional notions of expertise and status; dialogue events aimed at all participants – scientists and publics – having an equal opportunity for engagement and interaction.

Research into the impacts of dialogue events has indicated that they can be promising places for learning and attitude formation. Researchers have explored the balance between dialogue and learning, concluding that learning can occur in truly dialogic activities without resorting to the one-way information transmission model seen in other formats (Lehr *et al.*, 2007).

Dialogue can also influence attitudes – attitudes of publics and scientists towards biotechnology converged following a dialogue event and publics became more positive towards scientists (Zorn *et al.,* 2010). In contrast, focus groups with no scientists present caused public participants to become more concerned about biotechnology, and their attitudes became more extreme (Zorn *et al.*, 2006). The presence of an expert in the dialogue event had a positive impact in terms of encouraging more positive perspectives and attitudes.

Ideas about expertise and who counts as an expert have been debated in the field of science communication. Brian Wynne is a key figure in research around local expertise, championing the notion that it is not only external experts such as scientists who are knowledgeable about a subject, but that local non-scientists also have important expertise (Irwin & Wynne, 1996; Wynne, 1992). Wynne uses the case study of Cumbrian sheep farmers in the aftermath of the Chernobyl radioactive fallout; Wynne explores the farmers' discussion of their own expertise in relation to the disaster and their reactions to the scientific advice they received (Wynne, 1992). However, there may be limitations to the extent to which the work of Wynne and Irwin can be applied to the context of public engagement events. For example the farmers' in Wynne's study have extensive specific expertise, learned through many years of experience in one particular environment; visitors to the Natural History Museum may not have any experience with or expertise on the topic of the scientists' presentations. The application of that expertise relates to a very different problem in each context – debating a scientific issue or the fallout of a radioactive disaster affecting livelihoods and health. I do argue, however, that there is relevance in the work from Science and Technology Studies such as that of Wynne and Irwin to the current thesis, as it provides a reminder of alternative explanations, expertise, perspectives and experiences which may be relevant in the development of public engagement events. Whilst visitors may not have the same levels of expertise as in the example of the Cumbrian sheep farmers', many will nonetheless have life experiences and insights which should be recognised and acknowledged if the public engagement is to be relevant and accessible. Through the work of Wynne and others (for example Blok, Jensen, & Kaltoft, 2008) there has been recognition that public engagement must incorporate and engage many other experts and forms of expertise; in doing so, public engagement programmes are likely to create a more equitable forum for dialogue.

Dialogue events have been one way in which scientific experts have come into contact with various publics and shared their expertise. Although dialogue aims to engage all participants in an open and active way, there are naturally power imbalances and hierarchies which are negotiated and dynamic across the event (Davies, 2013). Whilst participation from non-scientists is important, researchers have highlighted the role for scientists to provide some new information in dialogue events, therefore scientists do have a role as experts in these types of public engagement activities (Davies *et al.*, 2009). Visitors to the Dana Centre in London stated that they valued the new information scientists provided in dialogue events, felt that this enabled them to take part in further discussions, and were frustrated when there was no new information presented from the scientist (Davies *et al.*, 2009). Scientists are experts, and, therefore, have a role in sharing their expertise not only in policy consultations, industry partnerships and in their professional research circles, but also in public engagement activities.

3.3.5 Attitudes of scientists and their self-identified roles in public engagement

So far this chapter has looked at the attitudes, perceptions and understandings of non-scientists. It is important, therefore, to consider the other side of the story, to look at the attitudes, perceptions and understandings of scientists themselves, towards the public, towards public engagement and their experiences of interacting with non-scientists, and towards their own roles and how they feel they are perceived by non-scientists. It is no coincidence that the first section of the chapter focusing on the public is much longer than this section which focuses on the scientists' perspective. The majority of the work into public engagement and science communication has been focused on public attitudes and non-scientists' experiences, for example looking at the attitudes of students. Little research has been carried out looking at how public engagement impacts on scientists, or what perceptions or stereotypes scientists hold about the public.

The majority of the work that has been carried out into the attitudes of scientists has focused on the reasons behind scientists being involved in public engagement, or the barriers to their participation. The following barriers to public engagement were identified using semi-structured interviews with early career scientists taking part in science cafes (Mizumachi, Matsuda, Kano, Kawakami, & Kato, 2011) (in order of most frequently mentioned to least frequent):

1. Could not perceive any benefit;
2. Apprehension about a dialogue with the public;
3. Troublesome and time consuming;
4. Outside the scope of their work;
5. Pressure to be an appropriate science representative.

Reasons 3 and 4 are not surprising given the pressures on scientists, and indeed any professional, to complete their often arduous work. Scientists, understandably, are reluctant to undertake additional tasks which will take time to carry out and prepare and which will not necessarily be recognised or rewarded by management. The other reasons relate to a possible lack of understanding and appreciation from scientists of the need and value of science communication and public engagement with scientists, and arguably stem from a lack of experience of interacting with the public. Other studies into the barriers scientists face in terms of participating in public engagement have found similar trends in terms of negative attitudes towards public engagement and perceived lack of skills and experience in communication dissuading scientists from participating in initiatives (Poliakoff & Webb, 2007). More and better research into the impacts of public engagement may provide encouragement and evidence to break down some of the barriers identified for scientists to take part in public engagement activities.

Some studies have looked at scientists' perceptions of the public, a reflection of the extensive research on public perceptions of scientists. Findings indicate that scientists believed the public are uninformed about science and, therefore, prone to making errors in judgement and also that the public is not interested in becoming more knowledgeable about scientific topics (Besley & Nisbet, 2013; Sturgis & Allum, 2004). These types of attitudes from scientists fit with the deficit model of science communication, whereby negative attitudes are thought to be caused by misinformation or lack of education (Sturgis & Allum, 2004). A broader perspective by scientists on why different publics might hold negative perceptions or concerns around science might enable them to engage more effectively to counter these attitudes and promote positive perceptions of scientists.

A deficit model perspective in scientists is supported by the main motivations they stated for being involved in science communication. Eighty per cent of scientists surveyed reported that they became involved in public engagement to inform – to ensure that the public is better informed about science more generally or about their particular subject specialism (Besley & Nisbet, 2013). Interestingly, only 10% of scientists said that the main reason they became involved in public engagement was to recruit students to the subject. This figure is in stark contrast to the high proportion of public engagement initiatives and research directed towards recruitment in science and engineering led by the science education communities.

3.4 Relevant theoretical perspectives

The literature reviewed above on the roles scientists play when taking part in public engagement highlight two key theoretical perspectives relevant to this work. Ideas around role modelling and perceptions of scientists stem from identity theory. Discussions around motivation, engagement and encouraging students to pursue science careers focus on interest development work. These two perspectives are, therefore, explored in more detail below.

3.4.1 Identity

Identity is a theme that emerges from the literature on attitudes to scientists and the roles scientists might play in public engagement. Understanding public perceptions of scientists in relation to identity is important, as perceptions determine whether individuals see science as 'something done by people like me'. Chapter 2 discussed how museum and out-of-school learning experiences can have an impact on identity and how museums may be contexts for identity development. In what follows, identity theory is discussed with a focus on science, as a relevant theoretical framework for this research.

Gee sees identity as being a certain 'kind of person' within a given context (Gee, 2000). This perspective on identity recognises that people have multiple identities. For example, a research scientist may also be a mother and a community activist. Gee describes four different views on identity: nature – which relates to a permanent state such as being white; institution – which is a position within a wider culture, for example being a head teacher; discourse – which relates to the type of person someone is and their individual attributes that come into play when recognised by others, such as being a generous person; and affinity – which is to do with practices and participation in certain activities with those of a shared interest, such as being interested in gardening. For the purposes of the current research, the affinity identity is most important, along with the discourse identity which develops when others refer to an individual as a 'science person'.

Brown, Reveles and Kelly (2005) also use the notion of the discourse identity – the way in which people talk about themselves to form and portray their own identity – in their discussion of scientific literacy. Individuals may attempt to control the impression they make upon others by giving certain signs about their identity, some made intentionally and some unintentionally (Goffman, 1959). Using these ideas within the context of science education and learning in museums, one might imagine someone, say a parent, who tells their friends and family: 'I'm not a science person, I don't get science, I never liked it at school'. They act as a 'non-science person', they avoid science museums themselves and might appear disengaged when they do take their children round a science-related institution.

Being a 'science person' would involve having established interests in science areas, identifying with science, seeing science as important and relevant, engaging with science activities and pursuing science-related hobbies. The notion of being a 'science person' relates to having 'science capital', those with higher levels of science capital engage more with science activities as part of their everyday life and are likely to have science resources and qualifications within their family, therefore, seeing science careers as attractive and achievable (Archer *et al.*, 2012b). Being a 'science person' may lead to a career in science, but not necessarily. Theories of science identity development and being a 'science person' have been explored by researchers focusing on the construction of science identities alongside other aspects of identities and the relevance of science in the life of the individual (Brickhouse, Lowery, & Schultz, 2000; Kozoll & Osborne, 2004; Tan & Barton, 2008). These themes of relevance, congruence with other aspects of identity, and the process of identity construction itself are important to the current research and returned to throughout the thesis.

When individuals examine their own identity in relation to those characteristics they associate with 'science people' and decide whether these two sets of identity characteristics are compatible a process of matching may take place (Taconis & Kessels, 2009). Through participation in science activities and interaction with other 'science people', individuals may develop their own science identities and become more involved in a 'science engagement' community of practice, where individuals participate in science related activities. Tan and Barton (2008) describe this development process as identities-in-practice in their study of two Latina students engaging with science.

Identity is said to be shaped by structural constructs, that is the structures and contexts in the cultural situation in which the individual operates. Identity is also shaped by agency, that is constructs from within the individual which are internally rather than externally driven (Holland *et al.*, 1998). Taking a psychological perspective on identity, research concentrates on the role of the individual in their own identity formation (agency), rather than the sociological and structural processes (structure) (Taconis & Kessels, 2009). A psychological focus is important in the current research which focuses on individual perceptions, attitudes and interest, which have internally-driven elements.

Various experiences and contexts provide support for the development of science identities, for example museum visits (for example see Chapter 2) and attitudes and interactions with their family. Building interest and capacity for these types of activities within families relates to the notion of increasing science capital (Archer *et al.*, 2012b), that is the qualifications, knowledge, interests, social contacts and activities relating to science within the family. When students experience support for their science identity from multiple different sources, or communities of practice, they are more likely to adopt such an identity and pursue this in the future (Aschbacher *et al.*, 2010).

Identification with others of similar potential identity is a way in which individuals can develop their own identities and furthermore take on the identity of a group with which they have much in common (Holland *et al.*, 1998). Identification with other individuals has been studied in relation to media characters (Cohen, 2001; Hoffner, 1996; Hoffner & Buchanan, 2005; Steinke, Applegate, Lapinski, Ryan, & Long, 2012). After studying wishful identification with scientists from television programmes, researchers concluded that there were some key attributes which encouraged students to identify with scientists and want to be like them. Intelligence, dominance, humour and success were important attributes leading to positive identification with scientists, with attractiveness important for female students and aggressiveness important for males (Steinke *et al.*, 2012). The current research involves face-to-face interactions with scientists; findings will be compared with those from studies exploring identification with media characters to determine whether meeting a person physically as opposed to encountering them in a virtual sense has an impact.

Out-of-school experiences have demonstrated promising impacts for the development of leaners' science identities, discussed in Chapter 2 in more detail. For example, a study of a summer astronomy camp explored science identity development through semi-structured interviews with students and staff (Fields, 2009). Impacts of the camp seemed to include students constructing science identities for themselves, in the 'affinity space' (Gee, 2004) of the camp. Fields uses Gee's idea of an affinity space, to describe the camp as somewhere individuals with shared interests and values interact, thus giving students the chance to develop their own identities in a social context. Everyday engagement with science, along with social support for science engagement may aid science identity development but may also lead to the development of identity as further away from science. For example, a further case study by Zimmerman (2012) showed that although a research subject may have had a strong interest in animals and participated in many activities relating to this interest, she used this engagement to distance herself from a science identity, an identity which was not supported by her friends and perceived as non-compatible with other elements of her identity as a girl. This work highlights how not all experiences will necessarily support science identity development in a positive direction; there is always the possibility that individuals will become more distant from science.

The perspectives of identity theory, identity work in museum experiences and science identities, pose the following relevant questions for the current research: does meeting scientists facilitate identity work on the part of the visitors? Does the experience of meeting scientists enable visitors to see similarities between themselves and the scientist, bringing them closer to the community of science? How does the experience of meeting scientists impact upon identity elements in visitors such as attitudes, perceptions, interests and values?

3.4.2 Interest

Interest relates to the personal curiosity, importance and relevance an individual attaches to a topic, and determines whether or not they are likely to be motivated to engage with it in future. Research into interest from the field of psychology is used in this research as it offers insights into how interest may be triggered, developed and maintained in the individual, as a result of connections to objects. Interest has both cognitive and emotional elements and, therefore, accords with the broad definition of learning used in this research. Interest is described as a person-object-relationship and is content-specific (following Krapp, 1999, 2002).

To describe the development of interest, Hidi and Renninger (2006) proposed the four phase model of interest. Interest firstly stems from a triggered situational interest, then builds into a maintained situational interest, before emerging at a less-developed individual interest and eventually becoming a well-developed individual interest which will last long-term. The importance of individuals discovering their own areas of interest has been stressed in the sense that an initial spark can lead to longer-term interest development (Krapp & Prenzel, 2011; Renninger, 2009). Although Krapp and Prenzel (2011) mention the importance of schools in providing opportunities for individuals to discover their own areas of interest, I would go further and say that museums and other out-of-school learning environments also have a crucial role. For example, Dohn has studied interest development as a result of visits to a zoo and aquarium (Dohn, 2011; 2013). Interest development can occur at any age, not necessarily only at school age; museums and science centres, for example, have a broader scope to spark interest in visitors of all ages in terms of their content and formats through which information is encountered. Consideration of the initial trigger and then later development of interest is of importance in this research which looks at how experiences in a museum may influence interest development and/or maintenance.

Interest is of particular relevance in this research as it has been strongly linked to learning and motivation (Dewey, 1913; Renninger, Hidi, & Krapp, 1992). In thinking about learning in the broad sense outlined in Chapter 2, therefore, if visitors leave the museum more interested in science and scientists, they will be more likely to want to engage further with it, find out more information about it and feel positively towards experiences involving science. Interest can thus promote scientific literacy and engagement with science whereas a lack of interest, on the other hand, is likely to discourage scientific literacy and engagement. The level of interest, learning and self-identification with science will influence an individual's scientific literacy and science engagement, which will in turn have an impact on what experiences they engage with in their future learning ecology.

Relevant questions for this research stemming from an interest perspective are: does meeting scientists facilitate interest development in visitors? If so, what areas of new interest emerge, and what are the areas of content visitors find less interesting? If any interest is triggered by the experience of meeting a scientist, does this develop into sustained longer-term interest, which may influence future continued engagement with science?

3.5 Research questions

A broad research focus was identified at the end of the previous chapter after consultation with Museum practitioners and a review of the research context. Following a closer examination of the academic literature around the impacts of meeting scientists and the roles scientists might play in public engagement, the research questions were further refined and two sub-questions added. These sub-questions reflect the shaping of the research through relevant theoretical perspectives and questions stemming from these frameworks. Drawing together what has been identified as most useful and important for the practice in which this research is based, what is known from previous research and the relevant questions arising from theoretical perspectives, the research focus has been reframed. The overarching research question is 'What are the impacts of meeting scientists on visitors to the Natural History Museum, London, and to what extent do the impacts last beyond the immediate experience?' and the two sub-questions are:

1. How does meeting a scientist impact visitors' identification *of* scientists?
2. How does meeting a scientist impact visitors' identification *with* scientists?

Identification *of* scientists refers to changes in perceptions of scientists, images of those working in science and ideas about who might or might not have a job in science. This research question is related to, but not exclusively about, traditional stereotypical images of scientists. Key work informing this research question includes that of Losh (2010) into adults' perceptions of scientists, as Losh focused on adults and not children as in the majority of work into perceptions of scientists, and focused on the non-physical characteristics such as personality, as well as the physical appearance of scientists in terms of perceptions. Other influential work for this thesis is Bennett and Hogarth's study (2009) which takes a broad and qualitative approach to studying perceptions of science and scientists, unlike much of the previous work in the field which has used quantitative measures such as surveys to study a limited set of perceptions.

It is hypothesised that meeting a scientist may change, or even confirm, previously held ideas obtained from elsewhere. Studying this area of impact also explores issues around the awareness and appreciation of the diversity of science jobs and careers and variety in the scientific field. To explore potential impacts around identification *of* scientists, work from the identity field will be drawn on, along with ideas from a conceptual ecology perspective on learning.

Identification *with* scientists relates to the personal connections people see with science and scientists and whether scientists are perceived as relevant and interesting or not. Identifying with something involves seeing similarities between it and everyday life or experiences. Identification with scientists involves developing empathy towards the scientists, interest in them and identifying common ideas or experiences. For those participants involved in the current study, identification with science might involve identifying similarities between themselves and the scientist they have met, so that they might identify with them on a personal level.

Key work informing the second research sub-question includes those studies exploring the notion that science is important and positive but not personally interesting – 'important but not for me' (Jenkins & Nelson, 2005; Bennett & Hogarth, 2009) – which point to the need for research exploring how science can be portrayed as more personally relevant and appealing. Similarly, key studies into identity have shaped this work, including those focusing on role models (Buck *et al.*, 2008) and theories of identity development (Gee, 2000; Holland *et al.*, 1998). It is these studies using identity as an analytic concept which, along with work from museum learning literature on identity work (Rounds, 2006), suggest that meeting scientists in a museum context may enable individuals to identify more closely with the scientist and see themselves more as a 'science person'. In this way, interview schedules and field notes were constructed to ensure that instances of positioning or identifying either more or less closely with the scientist could be collated and analysed. To explore impacts on identification *with* scientists, relevant work from interest development theories and identity work has been used, along with empirical work from public engagement with science.

The two areas of identification *of* and *with* scientists were chosen as they draw together the existing literature on attitudes to science and perceptions of scientists, whilst also taking the more recent perspective of looking at identity development in individuals. Looking at these two areas of perceptions and connections simultaneously in a museum setting is one way in which this thesis builds on the existing knowledge in the field.

3.6 Conclusions

A review of the literature from public engagement and science education research has indicated that scientists may play many roles when taking part in public engagement activities. This diversity of roles may lead to a variety of impacts on the individuals they interact with. Following from Chapter 2, therefore, it is suggested that interactions with scientists in museums may lead to impacts on the visitors and students involved relating to identity development and interest, with the potential to contribute to the development of scientific literacy and engagement. Refined research questions were presented above; the research will study the impact of meeting scientists on visitors' identification of and with scientists. The following chapter describes the methodology and methods adopted to address these research questions.

Chapter 4: Methodology and Methods

4.1 Introduction

This chapter outlines the methodology and methods employed in this thesis, addressing the research questions outlined in Chapters 2 and 3. This study explores the impacts of meeting scientists on visitors to the Natural History Museum, London and in particular whether meeting scientists has an impact on visitors' identification *of* and *with* scientists. The methodology of this research relates to the research questions and theoretical perspectives discussed in earlier chapters, including interest development theories (for example Hidi & Renninger, 2006; Krapp, 2002; Renninger *et al.*, 1992), sociocultural perspectives on learning in museums (Leinhardt *et al.*, 2002) and theories around identity and identity development (for example Holland *et al.*, 1998; Tan & Barton, 2008).

I begin this section with a brief overview of the research approach. A pilot study was carried out in the early stages of this research to refine the methods used and a brief description is given here along with the adaptations it led to. I then discuss issues of validity, reliability and reflexivity in this study. I go on to cover sampling and recruitment of participants from the event audiences. Strategies used for data analysis are covered next, presenting coding frames and explaining the procedures through which the outcomes and conclusions of this research were reached, leading into the subsequent three chapters which describe the research findings. The chapter ends with a discussion of the limitations of this research.

4.2 Research approach

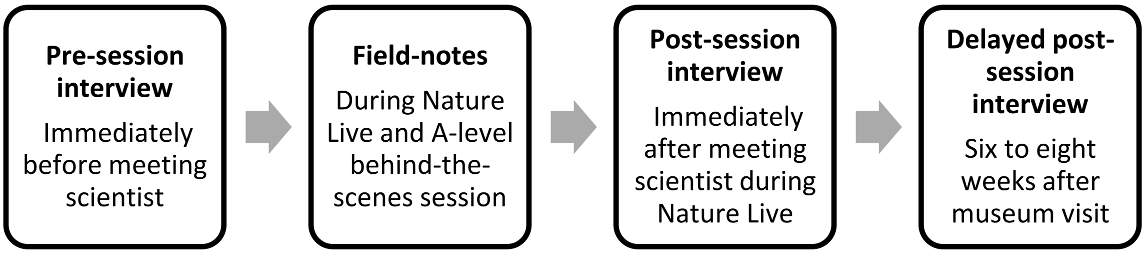
Table 1 summarises the research approach, including research questions, theoretical frameworks, data collected and how the data were analysed in order to reach the conclusions.

Table 1. Summary of research approach and methods used to address the research questions.

Research questions	Theoretical frameworks	Data	Analysis
What are the impacts of meeting scientists on visitors and students, and to what extent do these impacts last beyond the immediate experience?	• Museum learning theory (Hein, 1998; Leinhardt *et al.*, 2002) • Interest development (Hidi & Renninger, 2006; Krapp, 2002) • Identity theory (Gee, 2000; Holland *et al.*, 1998)	• Interview transcripts	• Iterative coding of interview responses
a) What are the impacts of meeting scientists on visitors' identification *of* scientists?	• Identity theory (Gee, 2000; Holland *et al.*, 1998) • Conceptual ecology work (diSessa, 2002)	• Interview transcripts • Field-notes	• Iterative coding of interview responses • Analysis of descriptors used and changes in descriptor use • Field-note analysis of portrayal of scientists in events
b) What are the impacts of meeting scientists on visitors' identification *with* scientists?	• Interest development (Hidi & Renninger, 2006; Krapp, 2002) • Identity work (Gee, 2000; Holland *et al.*, 1998; Rounds, 2006)	• Interview transcripts • Field-notes	• Iterative coding of interview responses • Analysis of questions generated for scientists as interest indicators (following France & Bay, 2010) • Field-note analysis of social positioning within events

In order to illustrate the time-points at which the data mentioned in Table 1 were collected, Figure 3 illustrates the study design. This research used a pre-post-post research design to collect interview data, with field-notes produced during the event itself. Data were collected across different time slots so that any changes in, or strengthening of, visitors' perceptions, attitudes and interests, could be more confidently attributed to meeting a scientist.

Figure 3. Study design.



4.2.1 A qualitative approach

This research adopts a qualitative approach to explore the impacts of meeting scientists on museum visitors. The study focus is on visitors' perceptions, attitudes, expectations and interests, along with the connections visitors make between the scientist's life and experience and their own. A qualitative approach, therefore, appeared most suited to this research, as it allows the researcher to explore the affective impacts on visitors in a broad manner and in depth. Unlike earlier studies into the impacts of museum experiences, this research is not focused on conceptual understandings but on an open range of impacts. Such an approach is now becoming more recognised in research into learning in out-of-school contexts (Duschl, 2008). Evaluation is encouraged that focuses on more than exhibition and learning outcomes; keeping a broad perspective on the impacts that might occur may be one way to explore how programmes impact upon visitors in a personally meaningful way rather than in ways only tied to the outcomes (Pekarik, 2010). A qualitative approach, therefore, is most suitable for the current study, enabling the research to be kept relatively open-ended.

Common principles of qualitative studies were collated by Silverman and are indicative of the current research (following Silverman, 2011, p. 5):

i) *Qualitative studies often begin with a single case study, chosen because of convenience or particular interest*

This study focuses on the Nature Live and A-level behind-the-scenes days at the Natural History Museum as case studies, in order to study the impacts of meeting scientists and explore concepts which are relevant to other museums and learning experiences in general.

ii) *Qualitative studies often investigate naturally occurring phenomena in the context in which they arise, rather than in a controlled setting*

Nature Live and A-level behind-the-scenes days are existing parts of the Museum programme, not planned interventions for the purpose of this research. Study participants were existing visitors, those who had made a decision to attend the session and visit the Museum, before being invited to participate in the study.

iii) *Hypotheses for qualitative studies are usually generated from the analysis of the data, rather than decided from the outset and tested*

The basis of this research relies on a hypothesis that meeting a Museum scientist during Nature Live events or A-level days will have some sort of impact on the visitor. This prediction is based on previous research into public engagement with science as reviewed in Chapters 2 and 3, where non-experts, for examples, families or school students, met scientists (France & Bay, 2010; Roth *et al.*, 2009; Zorn *et al.*, 2010) alongside research highlighting the impacts of social interactions in museums and science centres (for example Bamberger & Tal, 2008b; Leinhardt *et al.*, 2002). This literature-informed hypothesis warrants the study of meeting scientists over another aspect of the Museum programme. However, the exact nature of the impact was unknown before the data collection and analysis began; the impact may have been positive or negative, to do with perceptions or attitudes, shifts in interests or strengthening of views and opinions.

iv) *There are multiple ways to analyse qualitative data, there is no one agreed approach*

In order to investigate the research questions, data were collected on visitors' perceptions, interests and attitudes, along with contextual information on the meet-the-scientist events. Such a diversity of data presented many opportunities for data analysis and, therefore, multiple options were considered and explored in the pilot study to find the most suitable for the purposes of this research. As the potential impacts of meeting scientists were not predefined before data collection, an open-ended 'bottom-up' approach was deemed most suitable for the majority of data analysis in this study, in order for any unexpected impacts to be identified and accounted for.

v) *Where numbers are used in qualitative studies, this is usually in the form of descriptive statistics or in tables, rather than leading to statistical significance tests*

The data and analytic techniques used in this study are mostly qualitative, although a small amount of quantitative interpretation was carried out relating to visitors' questions to scientists and numeric data were used to illustrate the occurrence of a coding category, allowing for comparison between themes. Qualitative and quantitative approaches are by no means exclusive and often studies labelled as qualitative have some elements of quantitative analysis or numeric data and vice versa (Dillon & Wals, 2006).

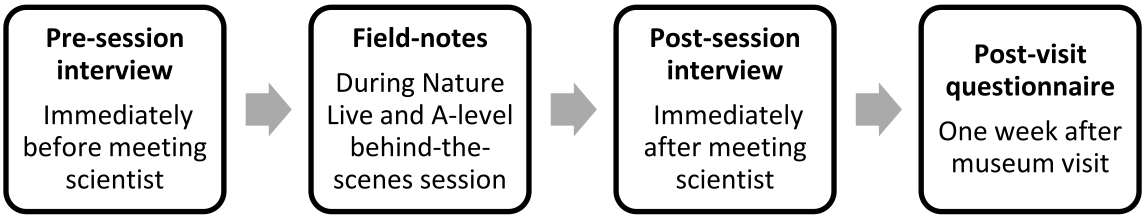
4.2.2 Developing the approach: the pilot study

In order to refine and adapt research methods, a pilot study was conducted involving 29 participants attending 16 events in total (15 Nature Live events and one A-level day). Research questions were formed from the initial focus identified through the modified Delphi study described in Chapter 2 and through review of the relevant literature which suggested that identity might be a useful area on which to focus attention. The questions were:
What impact does meeting a Museum scientist have on visitors to the Natural History Museum, London?

- In particular, what impacts does meeting a scientist have on elements of visitors' identities?
- Does meeting a scientist change visitors' perceptions of science or scientists?
- Does meeting a scientist influence the questions which visitors would like to ask scientists?

The data collection methods used in the pilot study were broadly similar to the main study, and are summarised in Figure 4. Reflective notes were made after each data collection session, on personal interview technique, interview schedule, recruitment success, any problems or issues that came to mind, things that worked well and things that needed addressing. These notes aided the development of the methods following the pilot study for the main data collection phase, informing changes made in particular to the phrasing and order of interview questions.

Figure 4. Pilot study design.



Participants were interviewed immediately before and immediately after the meet-the-scientist session and given a printed questionnaire which they were asked to complete after one week and post back to the researcher using the stamped addressed envelope provided. It was felt that asking participants to fill the questionnaire after any longer and post it back raised the chances of it getting lost or forgotten about. The response rate for the questionnaire was lower than hoped, only 11 questionnaires were returned out of a possible 29. It was felt, therefore, that a telephone interview could enable data to be collected in more depth and after a longer period than a postal questionnaire. The replacement of the questionnaire with a telephone interview was the main adaptation of the research methods following the pilot study. Preliminary findings from the pilot study indicated that this approach could be fruitful and, therefore, the main study of data collection began in November 2011.

Other modifications made as a result of the pilot study included those relating to sampling, recruitment and the interview schedule. Various ways of recruiting participants were trialled, including approaching visitors in the queue outside the Attenborough Studio and conducting the pre-session interview in the queue. In this approach the participants did not have to be those first approaching the studio (as in the recruitment approach later decided on), but could be the fifth or tenth, say, visitor in the queue which may have been a more random way of sampling. Conducting interviews in the queue, however, was less comfortable and relaxed for both interviewer and interviewee; participants seemed aware of the other visitors around them and gave shorter answers. The sampling approach decided on and used in the main study involved approaching the first visitor to show an interest in the event in the area surrounding the Studio (not necessarily already beginning a queue) and conducting the interview on seats in a quiet gallery space nearby. More details on the sampling and recruitment methods are below.

The interview schedule was adapted as a result of the pilot study, where questions were trialled and developed. The initial interview schedule involved questions about past attitudes to science, for example about how the interviewee had found science at school. It was felt, however, during analysis of this preliminary data that this line of questioning did not contribute to the investigation of the research questions around the impact of meeting scientists, and elicited interesting but unnecessary information. The questions about past attitudes to science, therefore, were removed. Different ways of phrasing and posing questions were experimented with, along with the order of the questions, and the interview schedule was tweaked after each pilot interview to ensure questions were clear, easy to understand, the interview had a conversational feel and the participants were encouraged to provide full and considered responses.

4.2.3 Research methodology

This research is predominantly situated in the objective realm of ontology. Ontology is the study of the nature of reality and relates to the subject under study (Dillon & Wals, 2006). Within research in the objective realm, methods focus on what is observable and measurable to the researcher (Carspecken, 1996). In this research, the objects of study are the attitudes, feelings and perceptions of visitors towards science and the scientists they meet and their ideas about the impacts of meeting scientists. These objects of study are shared with the researcher in the social context of the interview and are directly observable to the researcher in the words of the participant.

Epistemology relates to how the subject of interest is studied and how knowledge is made within the research. Kelly *et al*. (2012) review three different epistemological perspectives – disciplinary, personal and social practice. This research is predominantly grounded in the personal epistemological perspective; the study focuses on the words of the visitors, their ideas, perceptions and understandings. There are elements of this study which may fit within a social practice perspective of epistemology. In the social practice perspective, knowledge is said to arise from a person's particular social position, group or context. In this research visitors sometimes base their reports of the impact of the interaction with a scientist from their position among the Nature Live audience that day, in relation to other members of the audience. However, the interviews and, therefore, the data are predominantly focused on the visitors themselves and their own personal notions of impacts following the interaction with the scientist, rather than the social context in which these impacts arise. It is logical, therefore, to conclude that this research falls mostly in the personal perspective of epistemology, whilst recognising that the three perspectives may not be as separate and distinct as might first appear.

Axiology is concerned with carrying out ethical research and letting 'right' and 'good' values guide a study. During this research, ethical guidelines were consulted to ensure that the research was carried out in an ethical way, for example the British Educational Research Association's 'Ethical Guidelines for Educational Research' (2011) and the Economic and Social Research Council's 'Framework for Research Ethics' (2010). These guidelines stress the need to ensure the confidentiality of participants, to anonymise the data collected and avoid distressing or upsetting participants in any way, for example through asking about sensitive or controversial topics in interviews. Silverman (2010) adds to these general ethical guidelines by listing some principles to follow to conduct ethical qualitative research. These principles include emphasising the voluntary rather than compulsory nature of participation in the study and obtaining informed consent from the participants before they take part.

Before conducting both the pilot study and the main phase of data collection, applications were made for ethical approval from the King's Research Ethics Committee, both of which were granted (reference numbers REP(EM)/10/11-42 and REP(EM)/10/11-72). In the light of guidance from the literature, research councils, King's Research Ethics Committee feedback and training seminars covering research ethics, a number of steps were taken to ensure the study was conducted as ethically as possible. These steps included:

- Information sheets were given to participants to explain the purpose of the study and what would be involved should they take part. After participants had read the sheet there was an opportunity to ask questions about the study. Approximately one in every five visitors asked a question, including what subject my research was in and what I had studied previously. Visitors also asked questions about the Nature Live event, for example if the events happened every day. No questions were asked that gave me reason to believe the participant was concerned by the study in any way, or had not understood the briefing information.
- Consent forms were given to the participants to sign before the study began. Participants were asked to tick a number of boxes to confirm that they were aware and happy with key points, for example with the interview being recorded.
- A comfortable, relaxing situation was created for the interviews – they were held in seated areas of the Museum galleries near to the Attenborough Studio where the Nature Live events took place. The interview was designed to be friendly and conversational and it was stressed that participants could leave at any time should they wish. Pre-session and delayed post-session interviews with students were conducted in classrooms or rooms of the school with which they were familiar.

- Participants were asked to pick a pseudonym for themselves, so that they would remain anonymous.
- Data recordings, participants' contact details and all interview transcripts were stored in a secure and confidential manner, either in a locked filing cabinet, or in a password-protected folder on a hard-drive.
- The study was explained fully to the scientists and hosts taking part in the sessions used for data collection, with the chance for them to ask questions. The data collection schedule was communicated to the relevant scientists and hosts in advance, so that they could request for their event not to be included in data collection should they wish. No scientists or hosts made such a request.
- The research was also explained thoroughly to the teachers of the visiting A-level groups and a specific information sheet was created for the teachers which explained what would be involved if their students took part in the study.

Axiology relates not only to carrying out research which is ethical, but also research of good quality. Research of good quality is strongly underpinned by theory, uses methods which are appropriate to the research questions and study focus, generates reliable and valid findings and, ideally, has some application and implications to practice and policy (Silverman, 2010). Efforts were made at every stage of the research process to ensure that the study was of good quality: training sessions were attended as and when appropriate, researchers both at King's and elsewhere were consulted about methods and study design, and a pilot study was conducted leading to further development of the main study. Finally, science communication practitioners and staff at the Museum were consulted and involved at a number of stages to ensure that the research has direct relevance to museum practice, both within the Natural History Museum and more widely.

4.2.4 Validity and reliability

Good quality research generates findings which are both valid and reliable.

i) Validity

Validity relates to whether the conclusions reached and claims made are an accurate and plausible reflection of the data. For example, Creswell (2012) discusses two types of validity; internal and external (following Shadish, Cook, & Campbell, 2002). Internal validity is to do with the conclusions drawn about the specific research case and the cause and effect relationships within the data set. External validity, on the other hand, is to do with how well the cause and effect relationships identified in the data set can be applied outside the study context to other examples, settings, museums and audiences. Ideas about internal and external validity mirror the concepts of convergence and coverance (Gee, 2005; McCallie, 2010). Coverance describes how well findings apply to other settings and contexts, as an example here from research on argumentation in dialogue events illustrates:

> *Claims are more likely to be valid when they are found to apply to a greater number of related situations, such as dialogue events at a number of venues and on a number of topics*. (McCallie, 2010, p. 132)

This notion of coverance is consistent with the idea of external validity mentioned above. Aiming for a high level of coverance within this research, interviews were conducted with many different members of the audience of different ages, genders, ethnic backgrounds and visiting as part of different social groupings or alone. The events studied also took place at different times of the year. Various scientific topics were covered and were presented by different hosts and scientists from all of the Science departments in the Museum. Coverance could be increased in further work by repeating the study at a different venue, building from this initial research which contributes to the knowledge base around meeting scientists in museums.

Convergence is consistent with the idea of internal validity, establishing whether or not the conclusions reached are reflective of the data. Convergence is achieved by asking many questions of the data set, approaching analysis in a number of overlapping ways, so that the findings gained from these different approaches can be compared for consistency. The more consistent and coherent the conclusions reached by different questions and approaches to data analysis, the more likely the findings are to be valid. This study takes multiple approaches to data analysis, to increase levels of convergence.

Approaching data analysis from multiple angles reflects the idea of triangulating data sources. Triangulation – studying the same research question from different but related data sources – aids researchers in becoming confident in the validity of their findings, overcoming the limitations of each specific data collection method used and ensuring that no outcomes or impacts are being excluded due to the nature of the research methods. This study takes a mixed methods approach in that it combines multiple methods of data collection and analysis with elements of qualitative and quantitative work.

Interview transcripts form the primary data source in this research and they are triangulated with field-notes from the events and records of the questions that visitors asked scientists. These three different approaches to assessing the impacts of meeting scientists on visitors converge to give a more full and valid picture. A similar example is seen in a study of the impacts of a laboratory visit on secondary science students (Luehmann, 2009). Student perceptions were captured during exit surveys, forming the primary research data, but were supported by field-notes and video-recordings of the laboratory sessions as secondary data sources (Luehmann, 2009). Some advantages of this particular combination of data sources may be that the limitations of each research method are counteracted by comparison with data from other techniques. So, self-reported attitudes and impacts (such as in student or visitor interviews) are backed up with field-notes made by researchers and vice versa, field-notes, which may be more open to researcher bias are analysed alongside participants' own answers. Thus, triangulation of data strengthens the validity of the research.

ii) Reliability

Reliability in research refers to the consistency of the approach, the methods used and the analysis performed. Research with high reliability would yield similar outcomes should it be repeated by another researcher and, therefore, methods used are controlled so that any researcher bias has a minimal effect. Steps were taken to ensure that data collection was carried out in a consistent manner throughout the study to increase reliability of the data. For example, the interview schedule was used in all interviews. Although there was room in the interview for flexibility in terms of asking additional follow-up questions, using the schedule ensured that all key topics were covered in all interviews.

To ensure data analysis was reliable and without biased subjectivity, a proportion of the data set was coded by a second coder, codes compared, percentage agreement calculated and any differences resolved through discussion leading to mutual agreement on one code. Reliability of research is improved when data analysis is checked or verified by someone other than the main researcher (Denzin & Lincoln, 2005). The process of verification enables calculation of inter-rater reliability, that is the degree to which the two raters agree on the coding (Silverman, 2010). Inter-rater reliability is used to eliminate personal bias for certain themes or codes and requires themes to be clearly defined and explained. Areas of disagreement led to discussion around the themes and the creation of new codes, themes and relationships where necessary to reach agreement between coders. The initial percentage agreements for specific strands of coding are given in relevant sections throughout the thesis alongside discussions of the coding frames. Remaining disagreements were solved through discussion until a single code was decided upon by both coders and, therefore, 100% agreement was reached. The inter-rater reliability calculated from all of the double coded data gave an initial mean percentage agreement of 82%, before discussion and agreement on codes to 100%, and provides an indication of the reliability of the coding frameworks, interpretation and conclusions reached.

4.2.5 Reflexivity and the role of the researcher

The nature of the collaborative studentship through which my research is funded has meant that I have been an active member of both communities at King's College London and the Natural History Museum, London. These roles will have affected my perspective as a researcher and shaped this thesis. Whilst conducting the research I was conscious of these perspectives and their implications, particularly my role within the Museum's Research and Evaluation team, and took steps to ensure that the work I was carrying out was objective and critical, whilst remaining aware of the practical implications which may be of use to the Museum. For example, I used theoretical frameworks to ground my ideas and analysed my conclusions in relation to the work of others in the field. The reflective notes I took during my pilot study enabled me to refine my research techniques and consider my influence on the research. I have taken steps to minimise this influence where possible and these steps are also discussed alongside the methods below.

4.3 Research design

4.3.1 Study context: Selection of Nature Live events and A-level days

The format and nature of the Nature Live events and A-level behind-the-scenes days are described in section 2.5.3. Data were collected from 81 visitors attending 52 Nature Live events at the Museum during a seven-month period from 22nd November 2011 to 26th June 2012. Data were collected from 38 students attending nine A-level biology days, taking place from 7th November 2011 to 12th March 2012.

There are a number of key differences between each individual Nature Live event and A-level day. Firstly, the scientist is different for each Nature Live session with the exception of a small number of scientists who may repeat an event twice over a weekend, for example. The majority of scientists who speak at Nature Live events and on A-level days are from one of the five science departments in the Museum (Botany, Entomology, Zoology, Mineralogy and Palaeontology). Occasionally, however, speakers are from other departments, for example the Angela Marmont Centre for UK Biodiversity based in the Darwin Centre, or from external organisations, such as London Zoo. Selection of Nature Live events to study aimed for a spread of events involving different scientists from different departments to avoid a bias of one department over another. Fourteen scientists from the Zoology department took part in sampled Nature Live sessions, 10 from Entomology, seven from Palaeontology, six from each of Mineralogy and Botany, five from the Angela Marmont Centre and Department for Learning and four from external institutions. A-level Nature Live and behind-the-scenes sessions involved scientists from four of the five Museum science departments (eight from Palaeontology, seven from Botany, six from Zoology and two scientists from Entomology).

Another factor which varies between sessions is the host. During the data collection period seven hosts and one manager worked in the Nature Live team and facilitated events, two hosts have since left the Museum. At least one event facilitated by each of the eight Nature Live staff was included in the sample, to include a spread of individual hosting styles. For the A-level days, a member of the science educator staff accompanies the behind-the-scenes tours and occasionally begins the discussion between the scientist and students. Again, a spread of events from different science educator staff was aimed for when selecting sessions to include in this study. At the time of the research, eight educators delivered the A-level behind-the-scenes tours, six of whom led sessions included in this research. A-level Nature Live events were hosted by one of four of the Nature Live hosts; Fran[6], Emily and Maurice hosted two events each, Regina hosted three events.

Nature Live events are scheduled daily, with two events programmed per day at weekends and during school holidays. Audiences vary widely in their composition, particularly between weekends and school holidays where more families attend, and term-time week-days where there tend to be a higher proportion of adults. To reflect this composition change, hosts and scientists will often tailor the individual events to suit the time of year and day of the week so that events on the weekend, for example, are more suited to family audiences compared to those in the week during term-time. In planning the data collection, therefore, a spread of events from weekdays in term-time, weekends, and weekdays in school holiday periods was scheduled. Events were selected so that each type – weekend (n = 12), weekday (n = 28) and

[6] All names have been changed – participants and staff chose their own pseudonyms.

school holiday (n = 12), were represented in the proportions in which they occur in a full calendar year. The 52 events sampled were attended by 3,019 visitors in total, 2,301 adults and 719 children (a mean attendance of 44 adults and 14 children per event).

In total, 52 Nature Live events and nine A-level days were included in the main study (an additional 15 Nature Live events and one A-level day were included in the pilot study). Events were selected on a monthly basis, taking into account the aim to sample a range of events from different hosts, science departments and day. Data collection finished when the data saturation point had been reached (Glaser & Strauss, 1967; Rubin & Rubin, 1995). Saturation point is when participants' responses reveal little that is new to the researcher; the majority of responses and variations have been encountered and it is not necessary or beneficial to continue with data collection as no new topics or themes arise in the interviews. When interview responses were similar to those encountered before and no new themes appeared to be arising, no further events were scheduled to be included in the research and interviewing stopped. Data collection was concluded after interviewing 81 visitors at the 52 Nature Live events, along with 38 students at the nine A-level days. This sample size enabled an extensive data set to be gathered, without collecting unnecessary data.

4.3.2 Study population

Two groups of participants were involved in the current study – adults attending Nature Live events and A-level students attending behind-the-scenes days. The two different groups of participants will therefore be referred to as 'visitors' and 'students' respectively, to distinguish between participants from the two samples. The term 'participant' refers to both sets of interviewees.

Nature Live events are a popular part of the Museum's educational programme and attract around 30,000 visitors a year. The sessions are usually aimed at adults and family audiences with children aged 12 and above, with some events in school holidays and weekends aimed at families with children aged seven and above. The breakdown of audiences in terms of age varies depending on the timing and day of events, but on average consists of around 80% adults and 20% under 16-year-olds.

This study focused on older children and adult visitors to the Museum, involving visitors over the age of 16. This age group is interesting to concentrate on as many previous studies into museum learning and experiences have focused on children, families and school groups (for example DeWitt & Storksdieck, 2008; Sanford, 2010). Fewer studies have looked at the impacts on adults specifically (for one example see Briseño-Garzón *et al.*, 2007) and calls have been made for researchers to focus on adult scientific literacy in out-of-school settings (for example Lucas, 1983). Compared to research into the perceptions and occurrence of stereotypical views about scientists of teachers and students, the general adult population are under-researched in these areas (Losh, 2010). Lucas argues that to improve scientific literacy for all, science education before the age of 16 should be the beginning rather than the end of learning science for non-scientists (Lucas, 1982). Visitors over the age of 16 are past the current age of compulsory full-time education in the UK and, therefore, engagement with science will come from other aspects of their life, possibly in the form of museum visits, watching television documentaries, and relating it to their work or further study. The experience of meeting a scientist at the Museum will form part of their lifelong learning and engagement with science fitting in amongst a variety of other experiences. Furthermore, adults are the parents, grandparents, teachers, family and friends of parents of the next generation of children and scientists and, therefore, their attitudes will influence those of younger children (Losh, 2010; Archer *et al.*, 2012b; Archer *et al.*, 2013b).

For the Nature Live events, suitable participants were, therefore, defined as over the age of 16, visiting individually or as part of a group. Suitable groups were defined as consisting of at least one adult and no more than three adults and have a sufficient level of spoken English language to understand the preliminary information about the study. Groups or pairs of adults were interviewed together so as not to disrupt the social context of the visit. Larger groups were not approached for the study as the pilot study indicated that it was difficult to hear individual responses and more challenging to facilitate so that everyone had the opportunity to speak in the available time. Groups with more than two accompanying children (under 16 years of age) were also eliminated from the recruitment procedure as in the pilot study it was found that more children were distracting to the adults and interviews were often interrupted and cut short.

For the A-level events study, groups of four students were interviewed. Interviewing four students at a time enabled some of the students' conversations to be captured whilst still enabling the voices of individual students to be distinguished on the audio recordings. It was also hoped that these groups of four students from each A-level group would include some variety in terms of ability and interest in science, and, therefore, a wider range of impacts would be captured in the interview than if only one student per group had been interviewed. As there were fewer A-level days scheduled, it was also important to interview more students for each event. It was possible to interview four students at a time for the A-level groups, as the pre-session interview took place before the group visited the Museum, usually at the school. Whilst it was not possible to interview larger groups for the adult Nature Live events due to time-restrictions on the pre-session interviews, there was more time available for the A-level students and, therefore, larger interview groups could be facilitated.

4.3.3 Sampling and recruitment

The recruitment of Nature Live visitors took place outside the entrance of the Attenborough Studio. The first suitable individual or group to arrive in the area and express an interest in coming to the event was approached and invited to take part in the study. Expressions of interest in the event included talking amongst themselves about the session, asking what time the session started or where it was held and positive responses when told about the session by the visit planners[7]. The first group or individual to express an interest in the event was approached to maximise the time available for the pre-session interview before the start of the event.

It is possible that the first individual or group to turn up to the Studio area and express an interest in the session could have been those who knew about the session beforehand, had come especially to the Museum to see the event, or had come to events before. This situation might lead to the sample being biased in that participants would be those visitors who were most keen to come to the event, had a good idea of what they were expecting and why they were coming. Had the recruitment focused only on the first visitor or group of visitors to enter the queuing area for the Studio, marked out with Tensabarriers (i.e., queuing devices), this bias may have been present and significant. However, this strategy was not used – instead any visitor who entered the wider vicinity of the Studio in the base of the Cocoon building expressing an interest was approached. From experiences in the pilot study, it was noted that often the first visitors to express an interest in the session were those who had come across the area by chance and were told about the event by a visit planner nearby. The sample is not necessarily skewed, therefore, towards those with a prior interest and keen motivation in coming to the Nature Live, but represents a more varied sample of visitors.

Recruitment of the A-level students to the study depended on which schools were booked in to the A-level days over the data collection period (November 2011 to June 2012). The number

[7] Visit planners are museum staff employed to promote events, activities and exhibitions and to help visitors to navigate the museum.

of A-level days available was limited as these are only programmed on Mondays in autumn and spring terms and when there are scientists and hosts available to meet the students. The selection of the four students from each school who took part in the study was decided by the accompanying teachers, although instructions were given to the teachers that these four students should be happy to take part and need not, by any means, be the highest achieving or most interested in science - in fact a mix of ability and interest was preferable. This guidance was given so as to encourage teachers to nominate a range of students for the study.

4.3.4 Study design

The pre-post-post design was used to gain data at three intervals around the interaction between scientists and visitors. Conducting a pre-session interview was necessary as it enabled pre-existing attitudes, beliefs and expectations to be explored, providing a baseline from which to compare those reported after meeting a scientist. The pre-session interview was particularly important in this study as it allowed me to ask about any questions that participants may already have had which they wanted to ask the scientist. The pre-session interview also allowed me to compare the topics of these questions with those given at later stages to track changes in topics of interest, a key line of investigation in this work.

A post-session interview was conducted straight after the session, allowing participants to talk in detail about what they had experienced, their first impressions and the immediate impacts they had felt the session had on them. This approach enabled me to immediately identify any questions the participants might have wanted to ask the scientist if they had had more time with them.

In addition to the immediate post-session interview, a delayed post-session interview was conducted six to eight weeks after the original visit, over the telephone or via Skype. Conducting a second post-intervention interview was important as it allowed the longevity of any reported impacts of meeting scientists to be tested, at a second, longer-term interval. Two months was decided as a suitable interval; participants would have returned to the 'norm' of their own daily routines, but it is also a short enough interval to be able to follow-up with all participants in the scope of this study and to reduce the likelihood that participants may have moved or changed their phone number, as might be the case if the follow-up interval was longer.

The delayed post-session interviews explored what participants could remember about the event, their perceived benefits of the session and if anything they had experienced in the session had subsequently cropped up in other aspects of their life, for example had they looked up any more information, or used the experience in their own work in any way. It was also a chance to see if participants had carried out any follow-up activities they might have mentioned in the post-session interview, for example had they changed their chocolate buying habits as they said they were going to immediately after the session on chocolate production by a Museum botanist? A similar rationale was applied to the use of a delayed post-session questionnaire design in a study into visitors' perceptions of the impacts of a visit to a science centre on their own thinking (Rennie & Johnston, 2007). Rennie and Johnston argue that the delayed post-session approach allows 'time for participants to reflect upon and to take actions consequent to, their science centre visit' (2007, p. 168). And finally, in the current research, participants were asked for a third time if they had any questions they would like to ask the scientist, should they meet them again.

4.4 Data

4.4.1 Types of data collected

In order to explore what impact meeting scientists had on the visitors and students involved and to explore what those impacts were, two types of data were required. Data indicating the thoughts, views and feelings of the visitors were needed to pinpoint any changes or impacts. These data were collected via interviews and transcribed for analysis. Secondly, data on the interaction itself were useful in terms of contextualising the impacts observed and, therefore, field-notes were taken from each Nature Live and A-level session. To give a sense of the size of the data set, each Nature Live event resulted in an interview set of on average 25 minutes 7 seconds and two pages of field-notes.

Data were collected using interviews in a very open manner, rather than using a fixed-response method such as a questionnaire or structured observation. Many previous studies into attitudes to science and scientists have used surveys and closed questions, generating quantitative data. These methods do not enable unexpected outcomes to be studied or particular findings to be probed in more detail during the data collection itself. The data collection methods were open-response and interviews were semi-structured to explore the breadth of impacts meeting scientists might have had.

A similar line of thinking was argued in Bennett and Hogarth's 2009 study looking at students' attitudes to science and school science in particular. Bennett and Hogarth (2009) developed the Attitudes to School Science and Science Instrument which collected descriptive and explanatory data on students' attitudes to science. Bennett and Hogarth go beyond other attitudinal studies which have led to a 'broad brushstroke', as they term it, overview of attitudes towards science, but which leave much to be probed further. I follow Bennett and Hogarth's lead by also leaving room in the open nature of the data collection for interesting directions to be pursued and probed further, gaining a deeper insight into the area of attitudes to science and scientists. Such an open nature of data collection fits with recommendations for assessing impact and learning in museums and other out-of-school contexts. Michalchik and Gallagher (2010) recommend that assessment methods focus on outcomes that are important to visitors, rather than pre-determined impacts important to researchers.

4.4.2 Interviews

The main data collection method used in this study was interviewing. Interviews are defined as 'an interpersonal situation, a conversation between two partners about a theme of mutual interest' (Kvale & Brinkmann, 2009, p. 123). Interviews are a useful way of obtaining qualitative, descriptive and in-depth data, in an open-ended manner with the opportunity to follow unexpected but relevant directions and ask for clarification (Creswell, 2012; Denzin & Lincoln, 2005).

Interviews in this study were semi-structured; I asked questions following prompts on an interview schedule, focusing on the perceptions, expectations and attitudes of the visitors towards museum science and scientists and the experience of meeting the scientist in the Nature Live event or A-level day (see Appendices II and III for interview prompt schedules used). There was flexibility in the schedule in terms of the order of questions should it be more relevant to the conversation to ask one question before it appears in the schedule. Follow-up questions, clarification questions and asking for more information were also added to the interview when I felt these would be relevant to the study.

Interviewing in this way has been referred to as a craft, reflecting the personal skills of the researcher to adapt to the situation and the information given by the interviewee in developing the art of asking suitable follow-up questions, and in posing questions which elicit fruitful answers (Kvale & Brinkmann, 2009). This craft perspective on interviewing is adopted in this study as opposed to the method perspective, which sees interviewing as a rigid procedure with little flexibility (Kvale & Brinkmann, 2009). The interview was carried out much like a conversation, I did not refer obviously to the schedule, just glancing at it when necessary, and no notes were taken – the whole interview was recorded on a voice recorder. I showed interest in the interviewees and what they were saying, aiming to reduce any anxiety or nervousness about being interviewed (Rubin & Rubin, 1995). These steps were adopted aiming to make the interview feel as natural and relaxed as possible for the visitors.

During the interviews, visitors and students were asked about the questions they might like to ask the scientists. The topics of these questions were used as indicators of the areas in which visitors were interested. It should be mentioned here that questions are defined as expressions of interest in finding out more information – they do not need to be grammatically phrased as a question specifically, but could be 'I would like to know why…' or 'I'd ask a scientist more about…'. These comments are in contrast to interviewees merely stating that they found something interesting, with no expression that they would like further details or information.

In previous research, student-generated questions have been used to demonstrate areas of interest, with students asking questions about the areas they are interested in finding out more about. The development of student interests in biology according to age, gender and nationality has been studied using a decade's worth of questions posted to Ask-A-Scientist websites (Baram-Tsabari, Sethi, Bry, & Yarden, 2009). Teachers have also used student-generated questions to identify what students are interested in and, therefore, want to learn more about in their lessons (Chin & Brown, 2002; Chin & Chia, 2004; Chin & Osborne, 2008). Analysis of student questions is a useful tool for teaching, involving the student voice in the topics which are taught.

i) Justification

As explained above, the focus of this research is on the perceptions, interests and attitudes of visitors and students, in relation to meeting a scientist during their visit to the Natural History Museum. Rather than focusing only on conceptual understanding of science information, this study looks at a broader range of impacts. It has been argued that more naturalistic and open-ended research methods are suitable for investigating complex and broad learning impacts, therefore semi-structured interviews are a suitable research method for this purpose (Kisiel & Anderson, 2010).

Interviews are arguably the most suitable way of gaining insight into people's thoughts, attitudes and perceptions, by directly asking the interviewee about them, compared to attempting to observe or measure these factors in a more removed way (Punch, 2005). As Jones argues:

> *In order to understand other persons' constructions of reality, we would do well to ask them […] and to ask them in such a way that they can tell us in their terms (rather than imposed rigidly and a priori by ourselves) in a depth which addresses the rich context that is the substance of their meanings.* (1985, p. 46)

Asking visitors in an open-ended way about the impact of meeting scientists and allowing the visitors to describe a breadth of impacts in their own words, therefore, is a valid way to reach this information. However, there is a concern over the use of interviews and questionnaire data in that they rely on self-reported information from the participants. A discussion of the issues around self-reported data and how these issues were addressed in this study can be found in the limitations section (4.6).

Interviews have been used extensively in the field of science education and also with museum visitors. A pre- and post-interview design was used in museum research by Zimmerman *et al*. (2010). Family groups were interviewed before they began their visit to a science centre and then again immediately afterwards and were asked about their usual family activities, routines and previous experiences with science both at the centre and outside. Afterwards, families were interviewed about their attitudes towards the visit they had just experienced, how typical it was and what was each family member's favourite part. This study aimed to investigate how families make meaning and learn during visits to science centres and in particular whether there are differences between 'expert' families who visit science centres a lot and 'novice' families who may be on their first visit. The pre and post interview design enabled the behaviour and experiences of the family at the science centre to be contextualised around their expectations and everyday family behaviour.

ii) Role of the interviewer

I used the ideas of Kvale and Brinkmann when developing my interview technique for this research, thinking about interviewing as a craft and the interviewer as the craftsperson (Kvale & Brinkmann, 2009). I, therefore, guided the conversation, focused the talk on the relevant information and steered the interview in the direction most appropriate for the research questions, whilst still respecting the interviewee's interests. I was clear about the interview topic, in this case, the Nature Live event or A-level day attended, but tried not to lead participants in terms of giving extra information or personal opinion. I also tried to be sensitive to the interviewee, remembering what the interviewee had already said, asking for clarification on ambiguous points and maintaining a critical perspective when interpreting the words of the interviewee. In following this advice, effort was made to create an ethical and productive environment in which I could discuss the interview topic with the interviewee with the aim of generating good quality interview data.

iii) Quality interviews

Many researchers have discussed criteria for a high quality interview (for example Silverman, 2010). One such list of quality indicators relates to the perspective of interviewing as a craft (following Kvale & Brinkmann, 2009, p. 164):

- The extent of spontaneous, rich, specific and relevant answers from the interviewee;
- The extent of short interviewer questions and longer interviewee answers;
- The degree to which the interviewer follows up and clarifies the meanings of the relevant aspects of the answers;
- To a large extent, the interview being interpreted throughout the interview;
- The interviewer attempting to verify his or her interpretations of the subject's answers over the course of the interview;
- The interview being "self-reported", a self-reliant story that hardly requires additional explanations.

This list of quality criteria was kept in mind throughout the development and conduct of the interviews themselves. For example, throughout each interview, I tried to keep questions as concise as possible, pausing and allowing time for longer interviewee answers, prompting for further information when necessary. I made efforts to clarify meanings of answers by repeating words or phrases, prompting interviewees to speak further about what they meant or add additional details to their answers. Repeating words or phrases and adding short sections of my own interpretation of answers allowed for verification of the interpretation as the interview progressed enabling the visitor to correct or change my interpretation if necessary. Interviewees predominantly agreed with the interpretations made and corrected interpretations in approximately 1 in 10 of the interviews. The interviews in this study, therefore, were closely tied to the proposed quality indicators from Kvale and Brinkmann (2009), increasing the validity of the data obtained.

iv) Interview development

Interview questions were constructed which stemmed from the original research questions, to ensure the interview had focus and direction (see Appendices II and III for examples of how the interview questions linked to the research questions). Questions were tested and developed further during the pilot study and my reflective notes helped identify questions which needed clarifying or changing in the interview. After the pilot study, therefore, a full interview schedule had been developed and tested with many visitors and I could be sure that the approach would produce interviews of good quality, questions were tightly tied to research questions, and elicited relevant, in-depth and focused information. The practice of asking the interview questions during the pilot study also ensured that a conversational style was achieved with a well-thought-out interview schedule underpinning the questioning, as recommended by Silverman (2010).

Interviews were carried out with individuals visiting alone, or as group interviews for the A-level students and visitors in groups. Interviews were not carried out individually for those visiting in groups so that taking part in the research did not disrupt the social context of the visit. Visitors could then talk to one another in the interview, prompt answers from each other, aid reflection from having heard the answers of the other participants and remind one another of other shared experiences relevant to the event (Cohen, Manion, & Morrison, 2011). Group interviews also reduced the interviewer voice as participants prompted one another to expand on their answers or add to what the other has said, helping interviewees feel more comfortable and at ease.

Pre-session and post-session interviews were carried out face-to-face, with visitors in the galleries of the Museum. Face-to-face interviewing has many advantages, enabling both parties to see one another's body language and facial expressions (Rubin & Rubin, 1995). This point is particularly important for the interviewer as they need to gauge the reactions of the interviewee to questions and to judge the mood of the interview. Hand gestures and signs can also be used in explanation of questions and answers, aiding clarification. Face-to-face interviewing was appropriate in this study for the pre-session and post-session interviews as visitors were already in the Museum and it was convenient to conduct the interview within the gallery space.

For the A-level groups, pre-session interviews were carried out a few days before the visit to the Museum. In most cases I travelled to the school and conducted the interviews face-to-face.

For one group, the pre-session interview was carried out via Skype and for another the interview was carried out over the telephone. The reason for these variations was that the two schools involved were located far away from London (where I am based) and it was not possible to travel to carry out the pre-session interview face-to-face.

For the delayed post-session interview, six to eight weeks after the original visit, the interviews were predominantly carried out over the telephone and in some cases via Skype, when visitors lived abroad. Telephone interviews were held at a time convenient to the visitor and from the comfort of their own home, therefore it was not necessary for me to travel to each participant to carry out the delayed post-session interview face-to-face. This approach also made it possible to interview participants from a wide geographical spread – for example telephone and Skype interviews were carried out with participants across the UK, in Hungary, Denmark, Singapore and Canada. Again, where possible, delayed post-session interviews with A-level students were carried out face-to-face at the school, or via telephone as a second option.

Despite their pragmatic advantages, telephone interviews are not a perfect research method, see section 4.6. However, the telephone interviews were more successful in terms of response rate and depth of data gained than the questionnaires used in the pilot study. The response rate for the telephone and Skype delayed post-session interviews was 79% (94 of the 119 participants).

v) Summary of interview data collected

To summarise, the interview data collected in terms of numbers of participants interviewed at each time period is shown in Table 2.

Table 2. Summary of individuals interviewed.

Study sample	Breakdown of sample	Time period		
		Pre-session	Post-session	Delayed post-session
Nature Live visitors	**Total participants interviewed (n = 81)**	**79**	**80**	**62**
	Interviewed individually	25	24	60
	Interviewed as part of a pair/group	54	56	2*
A-level students	**Total participants interviewed (n = 38)**	**28**	**36**	**32**
	Interviewed individually	4	0	7
	Interviewed as part of a pair/group	24	36	25

*The vast majority of the Nature Live follow-up delayed post-session interviews were carried out with individual participants over the telephone. For two participants a joint interview was conducted via Skype.

Nature Live visitors. Pre-session interviews were carried out with all participants with the exception of George and Sarah (from event NL-Zr[8]), who were recruited after the session as the first participant for that session had decided not to continue with the study due to time pressures. Although for this couple there were no pre-session data, additional questions were added at the start of the post-session interviews to explore some of their expectations held before the session. The mean pre-session interview duration was 5 minutes 3 seconds, with the shortest at 2 minutes 12 seconds and the longest at 9 minutes 58 seconds.

[8] Nature Live events were given reference codes from NL-A to NL-Z and NL-Za to NL-Zz.

All participants but one, therefore, took part in the second (post-session) interview. Post-session interviews were an average of 8 minutes 46 seconds in duration, with the shortest being 2 minutes 41 seconds and the longest being 29 minutes and 1 second.

Delayed post-session interviews were carried out over the telephone or via Skype when participants lived outside the UK. The delayed post-session interviews varied in terms of how long after the visit they took place. Follow-up interviews took place on average (mean) 61 days after the Nature Live event, with the shortest follow-up period being 40 days and the longest 97 days. This high degree of variation within the follow-up period was necessitated by the participants' schedules and availability. As a result of being flexible in arranging these interviews there was a high success rate in terms of the numbers of follow-up interviews that were carried out. Delayed post-session interviews were on average 13 minutes and 57 seconds in duration but ranged from 4 minutes 27 seconds to 36 minutes 17 seconds. This wide range can perhaps be attributed to the fact that participants were in their own homes and were more flexible with their own time and with some participants being more talkative than others.

A-level students. Interviews were carried out with 28 students before they visited the Museum. For two schools it had not been possible to schedule pre-session interviews with students due to teacher and student non-availability and late bookings by the school for the Museum programme. Two students were included in the data for School C[9] (Sahara and Safiya) as only one other student was available for the first scheduled delayed post-session interview scheduled at the school, so these additional students who had also attended the same A-level session volunteered to be involved so that a group interview could be carried out. These two students, therefore, were not involved in the pre-session or post-session interviews. Additional questions were asked in the delayed post-session interview for these two students to explore some of their expectations of, and immediate reactions to, the session. Although it is not an ideal situation to have these participants join midway through the study, I felt it more beneficial to conduct the delayed post-session interview with the original participant and the two extra participants, than to conduct the interview with the original student by herself, so that she had other students to bounce ideas around with in the same way she had done in the pre-session and post-sessions interviews. Pre-session interviews were carried out between three and six days before the school visited the Museum, with the mean being four days. Pre-

[9] Participating schools were given a reference code, from A – I, groups of study participants were given a corresponding code from AL-A to AL-I.

session interviews were on average 12 minutes and 28 seconds, with the shortest at 7 minutes 30 seconds and the longest at 22 minutes 21 seconds.

Interviews immediately after the meet-the-scientist sessions were carried out with 36 students. The only two students not involved in post-session interviews are those mentioned above, Sahara and Safiya, who were recruited for data collection at the delayed post-session stage. All post-session interviews took place during the lunch break on the day of the visit, immediately after the Nature Live session. The average length of post-session interviews was 9 minutes and 22 seconds, with the shortest interview being 5 minutes and 48 seconds and the longest being 13 minutes and 40 seconds.

Follow-up interviews were carried out with 32 of the 38 students. The majority of the interviews were carried out face-to-face with groups of students (7 groups, 25 students) but some individual telephone interviews were carried out where necessary (7 students). It was not possible to arrange a delayed post-session interview with one school (School E) due to teacher non-availability and two students from other school groups (James and Sophie) were absent from school on the days of their delayed post-session interviews so they could not be interviewed. A second delayed post-session interview was conducted for School C as three students from the original group of four taking part were absent on the day of the first scheduled follow-up. Follow-up interviews took place on average 62 days after the A-level day, with the shortest follow-up period being 46 days and the longest 78 days. The average length of interviews was 10 minutes 43 seconds, with the shortest being 6 minutes 30 seconds and the longest being 13 minutes 36 seconds.

4.4.3 Field-notes

The secondary data source, which complements the interview data and contextualises the conclusions reached, comes from the field-notes taken during the Nature Live events and A-level days. These field-notes provide descriptive information about the event, the content of the session, presentation styles of the host and scientist and any notable occurrences such as noisy visitors or a small audience.

Field-notes are the text recorded during a qualitative observation, forming a source of data about the event or activity studied (Creswell, 2012). Field-notes are used extensively in ethnographic research, where the researcher records situations and experiences as they take part in the group or context they are studying. The field-notes in the current study were taken as the researcher formed part of the audience and, therefore, were a form of participant observation. Field-notes can be taken in a structured way, with predetermined prompts or focus points, however in the current study they were taken in a more open way, with the researcher noting down occurrences, features and events as they appeared throughout the event.

Field-notes have been used successfully in many other studies into museum visits. For example, in the study mentioned above by Zimmerman *et al*. (2010), given as an example of a pre-post interview design, the researchers also took hand-written notes alongside video-recordings, of the families' visits, recording conversations between family members, evidence of learning and meaning-making and behaviour at different exhibits. The field-notes were then used alongside the interview data to study the processes that 'expert' families – those who visit science centres often – use to learn from exhibitions. Davies (2013) used field-notes to study the balance and negotiation of power within dialogue events at the Dana Centre, London.

In the pilot study, I took both descriptive and reflective field-notes. Reflective field-notes were used to record feelings, personal thoughts and questions. Descriptive field-notes were used to provide information about the situation, context and events. In this initial study, reflective field-notes helped to refine methods and techniques for the next stage of research, flagging up potential issues to follow-up or check and encouraging me to critique my own interviewing practice. Following the pilot study, during the main phase of data collection, I only took descriptive field-notes – I did not make reflective notes. This decision was made for two reasons. Firstly, I felt that the methods had been refined and improved significantly through the pilot study process and, therefore, reflective observations on the methods were not as useful. Secondly, the process of taking reflective field-notes had encouraged me to think about my own practice more automatically and, therefore, notes were no longer needed to prompt this thinking.

i) Justification

Field-notes taken in this study served two purposes. Firstly, they helped capture the diversity, variation and different components which made up each Nature Live event. It is important to have a record of these variations as it is possible that impacts identified may link to specific content or activities present in the events. For example, in a study into the effects of a half-day laboratory visit for science students, detailed field-notes of the laboratory sessions, along with film taken during the visit, formed a secondary source of data for the researchers to refer back to (Luehmann, 2009). Luehmann's field-notes supported and provided context to the primary data gained through interviewing the students and teachers involved and allowed for triangulation of data sources.

The second purpose of taking field-notes during the events was to record the questions visitors asked scientists during the sessions, particularly if any of the interviewees asked a question. Recording the questions from the session itself enabled the audience questions to be compared to the questions generated by the interviewees in the pre-session, post-session and delayed post-session interviews. Comparisons could then be made between questions asked when scientists were actually present and those asked in interviews when the scientist was not present, and also over time.

Field-notes were appropriate for this study because they provided the interview data with a context and they recorded the details and variation in the experiences participants may have encountered. Solely relying on video-recording the sessions would have been an alternative, however there is much information that is missed in relying solely on a recording. For example, the majority of the videoing focuses on the scientists and hosts rather than on the audience and their reaction. The recordings also did not capture the atmosphere of the audience in the same way, for example when there were a lot of fidgeting children, when the audience was laughing at the jokes made by the scientist, or when the audience members seemed distracted. However, field-notes may be more subjective, the researcher may only record the events they are interested in and, therefore, the data are biased. This point is especially true when taking field-notes in a relatively open and unstructured way, as adopted in this study. However, I was aware of this bias and made a conscious effort to note down all events with equal emphasis. Having a recording of the session to check against was useful, especially as I may have missed some occurrences the first time around whilst still writing the previous entry.

ii) Constructing field-notes

Field-notes were taken throughout each event observed. I took a seat towards the back of the Attenborough Studio, or kept to the back of the group during the A-level behind-the-scenes sessions. Notes were taken discreetly in a notebook about the content of the session, key topics spoken about, notable features of the presentation style of the scientist or host, for example if they used humour, introduced specimens, the mood and reactions of the audience and finally the questions asked by the audience. Any unusual events were also noted, such as the session being particularly busy, or the presence of a notably disruptive member of the audience.

Care was taken to record field-notes in the most discreet way, not being obvious or looking suspicious to the audience members. Scientists and hosts may also have felt uncomfortable with someone taking notes during their session, so again I was discreet when note-taking. Following appropriate ethical guidelines when taking field-notes is also important and the process was explained to the scientists and the hosts so that they understood the purpose of the study and had a chance to ask questions about it. Visitors were made aware of the observations and recordings of the session during the visit planner briefing before entering the Studio. Students were also made aware of the observations and recordings in their briefing at the start of the day. No visitors or students made a comment about the recordings.

Each event observed in this study was recorded by the Museum's Special Effects team. Events are recorded so that they can be uploaded to the Museum's website and for the Nature Live team to reflect on their own practice – recordings were not taken especially for the current research. Following each event, the recordings were watched back and field-notes typed up in a more full and organised way than the hand-written notes taken *in situ*. Key features missed in the first iteration of the notes were added and original field-notes were verified by watching the session again. An added advantage of watching the recordings of the events was that the questions asked by audience members could also be transcribed word for word to ensure the point of the question was not changed by my interpretation.

4.4.4 Additional descriptive data

The following data were collected from a short visitor questionnaire to gain demographic information on the participants involved. These data provide the descriptive context in which the study is based and are useful when comparing the findings to earlier studies.

i) Nature Live visitor data

Participants were selected to take part in the study from those already attending the selected Nature Live events. A total of 81 adults were involved, 35 males and 46 females. Sixteen participants were visiting individually, 36 with another adult, a friend or partner, and 29 with family, often including children[10]. Only interview data from adult participants were used in the study (see section 4.3.2). Participants ranged in age with the majority (n = 21) aged 25-34. Participants also ranged in ethnicity, with nine of the 16 options selected by participants. The majority of participants (n = 50) stated that they were 'White – British'.

During the interviews, participants were asked if they had a science background. Of the total of 81 participants, 25 had studied or were currently studying science to undergraduate level. The majority of participants were not scientists; 11 participants reported that they were currently working in science. The interpretation of which jobs count as 'in science' was left to the participants themselves, who usually elaborated on the specifics of their job, such as 'Yes, I'm an entomologist' or 'in behavioural ecology'.

ii) A-level student data

All students participating in this section of the research were studying for their AS or A-level biology qualifications. They attended the Museum as part of an organised visit with their school or college. In total, 38 students took part in this study, 19 males and 19 females. The participating students came from nine institutions: three academies, three independent schools, two state-run further education colleges and a US Department of Defence Dependents School. Three schools were situated in London boroughs and the others were from elsewhere in England. Seven of the institutions were co-educational, one was all boys and one was a girls' school.

4.5 Data analysis

The previous sections have described the types of data collected in the study, the purpose of collecting these types of data, methods through which the data were collected and the advantages and issues of using these methods. The following discussion describes how the data were analysed, beginning with how data were prepared for analysis. An example of a coded interview transcript and field notes have been provided in Appendices IV and V for illustration.

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[10] In some cases the rest of the family did not stay for the interview or Nature Live session but were looking around other areas of the museum.

4.5.1 Transcription

Before the interview data could be analysed, transcripts needed to be prepared from the audio-recording files. Transcription is the process by which oral data are transferred into written text (Cohen *et al.*, 2011). Through the process of transcription, certain elements of the data may be lost or changed. For example, body language and tone of voice cannot easily be recorded in an interview transcript. Transcripts are, therefore, at risk of putting too much emphasis on the words spoken and not enough recognition of the other implied data and data sources, such as body language and facial expressions.

Despite these issues, the process of transcription was necessary for this study in preparing the oral data for further analysis. As the primary focus of the current research is what visitors said and how this may change as a result of an intervention (meeting a scientist), additional, non-oral behaviours or the social contexts in which the interviews took place are less crucial to the interpretation of the data. Any visible cues that the interviewee was becoming bored or tired of the interview were picked up on the spot, for example checking their watch or phone, and the interview was continued more quickly so as not to delay the participant further. The decision, therefore, was taken to audio-record the interviews, as opposed to video-recording. The recordings of the interviews were transcribed verbatim, with the inclusion of emotional expressions such as 'hmm', 'erm' and sighing or laughing.

The importance of punctuation has been recognised in using and creating transcripts as it may have a huge impact on altering the meaning of what people have said (Poland, 2003)**.** Punctuation was added in this case, whilst transcribing the interviews, to best represent the meaning of what was said, using clues from the interviewee's tone of voice, recollection of body language and previous answers where necessary. However, I did not finish incomplete sentences or correct grammar, but used the words which were spoken, adding commas and dashes where it was felt appropriate. This method created an accurate representation of what interviewees said, without altering the meaning, whilst recognising that transcription is a phase of the interpretation and analysis.

Transcription can be an iterative and subjective process and, therefore, issues of validity and reliability must be considered. For this study, I transcribed the entire data set to ensure that transcription was as consistent as possible. The process also aided familiarity with the data set for later analysis. I made notes during transcription on conventions and rules to follow for future interview sets. This strategy ensured that the process was standardised and that the data set was prepared as consistently as possible for the next stage of analysis.

Following transcription, and during and following data analysis, copies of transcripts were created for each individual interviewed and were named corresponding to the individual participant. For instance, if two individuals had been interviewed at once, two copies of the same transcript would be created, one named after each participant. Transcripts were coded according to the individual – so, for example, in the transcript named 'Anne', only responses spoken by Anne were coded. This enabled analysis to focus on an individual level. Files were coded and stored in NVivo: a qualitative data analysis software. Once transcripts had been coded and checked, copies of the file (complete with coded annotations) were stored as external documents to the analysis software as a back-up. The analysis software stores the coded transcripts and coding framework, and enables all sections of transcripts coded under a certain category to be viewed at once, facilitating checking within codes and sorting of codes if necessary.

4.5.2 Analytic frameworks

This study uses a 'bottom-up', open analytic approach, which takes in part ideas from grounded theory, to analyse the participant responses within the interview transcripts. Grounded theory is based on the idea that theories arise from the data. No pre-decided theory or focus is placed on the data but, rather, the themes and patterns emerging from the data themselves are the basis of a new theory (Corbin & Strauss, 2008; Miles & Huberman, 1994). This study used 'bottom-up', open coding analysis, which is similar to grounded theory in that the themes arise from the data, but with the acknowledgement that analysis was carried out with research questions in mind. Relevant theoretical work was identified as a result of the literature review undertaken at the beginning of this study. The 'bottom-up' coding revealed findings and trends from the study data, which were then interpreted in light of the key literature identified. The themes emerging were not pre-determined, therefore, but were related to the themes of meeting scientists and the impacts of the interactions on interviewees, and then compared to the wider literature.

A similar approach to data analysis was adopted by Archer *et al*. (2012b) in their study focussing on the role of families in shaping children's perceptions of science. The initial phases of analysis were conducted in an iterative and open way, defining and adapting codes as the process continued. Code memos were created to aid 'bottom-up' coding, consisting of the name of the code, what the codes signify and any other thoughts on the codes (as suggested by Gibbs, 2007). The data analysis in the study by Archer *et al.* resulted in a typology of codes relating to family capital, habitus and children's aspirations and relationships with science. Subsequent stages of analysis in the study by Archer *et al*. were grounded in theoretical frameworks as are the interpretations and conclusions made in the current research.

What follows in this section is a brief description of the analytic framework implemented in this study in addressing the research questions outlined in Chapter 1. I include coding frames here, but descriptions of the codes used, frequency of occurrence, and examples of data will be discussed in more detail in the following chapters. Thematic coding was employed to address the broad research question about the impacts of meeting scientists on visitors in the 'bottom-up' open approach described above (Boyatzis, 1998). Thematic coding analysis is discussed by Braun and Clarke (2006), who summarise a six-stage guide to carrying out this type of analysis:

1. Familiarising yourself with your data;
2. Generating initial codes from the data;
3. Searching for themes amongst codes;
4. Reviewing themes through coding new data;
5. Defining and naming themes, organising in a framework or map;
6. Producing the report, representing the themes.

The above process was followed when analysing the data in this study. Braun and Clarke's definition of a theme is that it 'captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set' (2006, p. 80). Care was taken to give all data equal attention in the coding process, ensuring data analysis was thorough, logical, consistent and comprehensive and not only focused on codes which supported my predictions.

Through thematic coding analysis, particular data relevant to impacts of meeting scientists reported by the visitors were identified, coded and grouped into a coding frame. These themes provide an overview of the range of different impacts of meeting a scientist on museum visitors. The coding frame generated through this process of 'bottom-up' iterative thematic coding is presented in Table 3 for Nature Live visitors and Table 4 for A-level students.

Table 3. Coding frame from Nature Live visitor data.

Coding category	Sub-category
Descriptions of scientists	Pre-session expectations Retrospective expectations Post-session Delayed post-session Understanding the work of scientists
Impacts on interest in the subject/work of scientist	Sparking a new interest Adding to pre-existing interest Maintaining a pre-existing interest No impact on interest Interest as motivation (to attend museum and/or Nature Live event)
Learning	General learning Specific learning Learning as motivation (to attend museum and/or Nature Live event)
Making links (identifying with the scientist)	New connections to the subject Personal links – job or study Personal links – life experiences and interests Personal links – personality Personal links – places Positioning self in relation to others
Other and future engagement	Everyday engagement Follow-up research Continued engagement e.g., intentions to another Nature Live session
Personal scientific background	None / science until leaving school Studied science at university Currently working in science
Questions (following France and Bay's 2010 framework)	Personal Science information Science process Social and ethical issues Museum

	Other questions Comments about questions (e.g., questions individuals had but which were answered in session)
References to the experience or the event (valued by visitors)	Compared to other experiences Accessibility of information Interactivity Authentic, unique and exclusive experience Motivations for attending the event

Table 4. Coding frame from A-level student data.

Coding category	Sub-category
About the experience (valued by students)	Authenticity ('realness') Exclusivity (something 'special' or unique) Interactivity
Descriptions of scientists	Pre-session expectations Retrospective expectations Post-session Delayed post-session
Hopes for the A-level day	Learn something new Seeing specimens Meeting the scientists Fun experience New or renewed interest
Identification with scientists (around science careers)	Impacts on understanding and awareness of science careers Impacts on personal attitudes about science careers Reactions to invitations to get involved in work of scientist
Impacts around careers in science	Students' ideas and plans for study or careers General awareness of science careers Understanding of what science jobs entail Impacts on students' personal career plans
Learning	General learning Specific learning
Other and future engagement	Everyday conversations Changes in behaviour Follow-up research Impacts on attitudes and intentions in terms of returning to Nature Live and the Museum
Questions (following France and Bay's 2010 framework)	Personal Science information Science process Social and ethical issues

	Museum Other questions
Sources of expectations of scientists	Stereotypes associated with media images Attitudes towards subjects scientist was studying Prior experience of meeting scientist

Some of these impacts identified through open, 'bottom-up' coding link to the two sub-questions. Specific analysis was then also conducted to further explore the impacts relating to visitors' identification *of* and *with* scientists in further detail.

i) Visitors' identification of scientists

The first research question concerns visitors' perceptions of scientists and of 'who scientists are', possibly addressing stereotypical views of scientists. Quotes concerned with descriptions of scientists, expectations of what the scientists *will be* like, or statements of surprise about what the scientist they met *was* like were highlighted and coded from the interview transcripts. The analytic process relating to data on perceptions of scientists is summarised in Table 5 and is discussed further in Chapter 5.

Table 5. Summary of analysis relating to perceptions of scientists.

	Focus of coding	Level of analysis	Results of coding	Description	Example categorisations
Stage 1 focussing on descriptors	Descriptors used by participants	Across all participants and all interviews	11 categories of descriptor identified	Descriptor categories consist of descriptors with shared meaning or of a similar theme.	Experienced and knowledgeable Interesting and engaging
Stage 2 focussing on behaviour types	Descriptor categories represented in each interview	For individual participants, for each descriptor category, across all interviews	Six types of behaviour	Behaviour types describe how the presence of descriptors within a specific descriptor category changes (or not) over time.	Emerging Confirmation
Stage 3 focussing on behaviour groups	Behaviour types displayed by participants across descriptor categories	For individual participants, across all descriptor categories	Ten behaviour groups	Behaviour groups consist of individuals showing similar patterns of behaviours relating to	All changed Change; Revert

	perceptions of scientists over time

Adjectives or descriptive phrases used to describe the scientist were identified – and named 'descriptors'. Descriptors were grouped into 11 categories consisting of those with shared or similar meanings; initial inter-rater reliability for coding these descriptors into categories was 78%, and differences were resolved through discussion to result in 100% agreement. The coding frames for descriptors of scientists are provided in Table 6. Individual descriptors from each data set – Nature Live visitors and A-level students – were grouped under the same 11 categories, emerging from both data sets.

The descriptors used by individuals when speaking about scientists in interviews were compared over the three time-scales – pre-session, post-session and delayed post-session. This comparison led to the next stage of analysis whereby the presence or absence of descriptors in each category was coded under six behaviour types for each individual and for each descriptor category. Once behaviour types had been identified, individuals were coded by the types of behaviours they displayed in relation to changes in their perceptions of scientists, across all descriptor types. This process involved studying the behaviour types occurring for each descriptor category and assigning a code to an individual based on the combination of behaviour types they exhibited. The process of assigning individuals to different behaviour groups used a decision coding tree, presented in section 5.4.

The decision coding tree represents the analytic decisions made when assigning individuals to the ten behaviour groups – the third stage of analysis in Table 5. Groups were created based on differences in the types and combinations of behaviours participants exhibited in relation to perceptions of scientists. The tree illustrates the differences and relationships between the different groups in a similar way to outcome spaces. Outcome spaces were used by Yasry and Mancy (2012), following guidance from Sin (2010), to group students according to their views on the relationship between science and religion. Outcome spaces show how categories are decided upon, and illustrate where individuals in groups share characteristics with others in different groups and where they differ. In this thesis I use the term decision coding tree rather than an outcome space as this term more succinctly portrays how the tree was used to assign individuals to behaviour groups.

For each of the ten behaviour groups, one visitor was selected to be the example case individual. This individual was selected as they were representative of the other members of the group and illustrated the group clearly in their interview data. These illustrative case examples are then returned to throughout the thesis when discussing different themes and topics, to illustrate the impacts meeting scientists may have had on individual visitors.

Table 6. Categories of descriptors mentioned when speaking about scientists.

Category	Actual description used by participants	
	Nature Live visitors	**A-level students**
Approachable and Nice**	Approachable Chatty Chirpy Friendly Nice OK Positive Reasonable Smiley	Approachable Chatty Easy to relate to Friendly Lovely Nice Open
Confident and good communicator	Articulate Clear Confident Good communicator Good voice Personable Right level - not too complex Sociable Softly spoken Using simple language	Confident Hands-on with specimens/equipment Informative Not boring Outgoing Polite Presented well Well spoken

Experienced and knowledgeable expert*	Dedicated	Dedicated
	Experienced	Educated
	Focused	Expert in their field
	Impressive	Focused
	In field for years	Hard-working
	Knowledgeable	Intelligent
	Know what they are talking about	Knows a lot
	Professional	Knows what they are talking about
		Professional distinction
		Smart
		Well known in field
		Well read
Funny and entertaining**	Dynamic	A laugh
	Entertaining	Amazing
	Fun	Fun
	Giggly	Funny
	Humour	Good
	Lively	Good sense of humour
	Witty	Making jokes
Helping to learn**	Could answer questions	Able to explain
	Easy to understand	Caring
	Explained things well	Clear
	Informative	Could answer questions
	Made you want to know more	Easy to understand
	Patient	Helping to learn
	Wants to share information	Making sure you understood
		Right level for students
		Trusting
		Wanting to share knowledge

Interesting and engaging	Engaging Exciting Interactive Interesting Vibrant	Engaging Exciting Getting students involved Inspiring Interactive Interesting
'Normal' people and against the stereotype**	Could be anyone Didn't look like stereotypical scientist Down to Earth Normal chappy Northern accent Not expecting a stereotype Not your typical scientist Young	"Actually like real people" Normal guy Not academic Not that old Practical (rather than theoretical) Young
Not engaging and bad communicator	Assumes some knowledge Boring Nervous Not dynamic - could move around more Not entertaining Not good communicator Quiet Using complex terms	Assume something about students Boring Cheesy Distracted Nervous Not hands-on Not humourous Not interesting Not that happy Quiet Speaking in technical terms
Passionate and Enthusiastic	Enjoy their work Enthusiastic Excited High curiosity Interested in work Loves the subject Passionate	Engaged with topic Enjoys what they are doing Enthusiastic Excited Interested in what they do Keen Passionate Want to find more

Relaxed and	Casual	Cool
informal**	Comfortable	Informal
	Cool	Laid back
	Laid back	Relaxed
	Relaxed	
Stereotypical	Anoraks	Beards
scientist	Beard	Closed up
characteristics	Boffins	Crazy hair and glasses
	Don't go out in public	Eccentric
	Dusty	Like college professors
	Eccentric	Looks like Einstein
	Einstein	Nerdy
	Geeky	Not normal
	Glasses	Old
	In scientist bubble	Reserved
	Lab coat	Stuck in a lab
	Mad	Theoretical
	Microscope	Wears lab coats
	Middle-aged	Weird
	Nerds	
	Nutty professor	
	Older	
	Proper scientist	
	Quirky	
	Tall	
	Typical scientist	
	White/grey/crazy hair	
	Wooly	

*denotes those categories most relevant to scientists as experts; **denotes those categories most relevant to scientists as ‘everyday’.

Visitors and students spoke about themes of authenticity and exclusivity, and also informality and accessibility of the events – thus scientists were perceived as being experts or contrastingly ‘people like me’. Field-notes were also coded for occurrences of scientists being portrayed as experts, and being portrayed as ‘normal people’, to complement and add context to the interview data, see Table 7 below.

ii) Visitors' identification with scientists

The first analytic approach addressing identification *with* scientists dealt with the questions asked or generated by the visitor to ask the scientist. When the topics of visitors' questions changed, it indicated a shift in the topics visitors were most interested in. Coding of questions followed a framework put forward by France and Bay (2010) in their study of the questions students asked when meeting scientists during a visit to a research laboratory. This element of analysis did not, therefore, follow the other 'bottom-up', open analytic approach, but was an alternative approach used to triangulate the data. The following broad codes were used to categorise question topics: science information, citizen decisions, personal (questions about the scientist) and nature of science. One category was added for this study for questions about the Museum. More information about the question categories and examples of questions falling under these codes is presented in the data chapters (see Table 12, section 6.5). A shift towards a higher proportion of questions about the scientists themselves, their career and personal experiences of doing research, after the Nature Live event, might indicate that visitors were identifying more closely with the scientist as a result of meeting them. The coding using this framework was tested during the pilot study and indicated some promising results in terms of the changes in frequency of questions on different topics before and after meeting a scientist.

Another strategy for addressing this second research question was to take a more 'bottom-up' approach and again explore themes arising from the data (the resulting codes are presented in Tables 3 and 4). One of these themes related to visitors identifying with the scientists they met more or less closely. Themes arising from the data providing evidence for visitors making any links between their own personal experiences and that of the scientist were of particular interest in exploring this second research question. Visitors and students also indicated identification with scientists through how they positioned themselves in relation to the scientist and other members of the audience in their interview responses. Field-notes were also coded, therefore, for occurrences of social positioning in the events – evidence of scientists being portrayed as closer or further away from the audience members. This analysis of field-notes provided contextual data to triangulate with interview response data.

The use of two types of coding – iterative 'bottom-up' coding, and then the use of the analytic frame from France and Bay to study questions in more detail, strengthens the conclusions of the study in the following ways. Firstly, iterative coding enabled unexpected outcomes to be identified and took a more naturalistic approach to the data analysis, following the approach taken to interviewing in a relatively open manner. By adopting a more structured analytic frame to study questions in particular, the study was able to utilise previously tested methods and triangulate findings.

iii) Field-note analysis

The field-notes taken in Nature Live events and A-level behind-the-scenes tours were also analysed iteratively following a similar process to the interview analysis described above. Themes relevant to the research questions were identified in the field-note data and organised into a coding frame. The coding frame with categories and sub-categories is given in Table 7.

Table 7. Coding frame from field-note data.

Coding category	Sub-category
Expertise	General (unsupported statement, for example 'Ben is an expert in…') Consultancy Education Publishing
'Normality'	General (links to everyday life, work and popular culture – not specific) Comedy Other aspects from life of scientist outside of current work Vulnerability (on part of scientist)
Social positioning	Highlighting or making connections between audience and scientist Invitation for audience to become involved in work of scientist in some way Distancing – positioning the scientist as less close to audience
Questions from audience (following France and Bay's 2010 framework)	Personal Science information Science process Social and ethical issues Museum Other questions

4.5.3 Quality data analysis

Care was taken when adopting the strategies above to ensure that the data were interpreted in a rigorous, balanced and logical way. Biased subjectivity was avoided by treating all data in an open and fair way, not only focusing on the data which fitted in with pre-existing opinions or predictions. Biased subjectivity is to be avoided in conducting research, whereas perspectival subjectivity is an understandable result of utilising different analytic frameworks or lenses, as in this research and described above (Kvale & Brinkmann, 2009). Providing the perspectives taken are made explicit and justified, it is acceptable that analysis will have been influenced by specific perspectives.

Data needs to be interrogated and analysed in a way which reaches beyond merely coding and categorising the words of the interviewee, but interprets the meaning of these statements (Kvale & Brinkmann, 2009). Analysis must go beyond what is directly spoken to work out the structures operating behind the text and answers themselves. As noted by Braun and Clarke (2006), weak qualitative data analysis often simply uses the interview questions as the 'themes' identified and, therefore, good quality thematic analysis goes beyond merely describing the data, to making inferences and interpretations about what is behind the words spoken. This depth of analysis was aimed for in the current research. Existing literature and theoretical frameworks were drawn upon again in this phase of the study, to interrogate themes and patterns emerging and ensure the conclusions reached were both grounded in theory and of relevance beyond this research.

4.6 Research limitations

Despite the precautions taken in conducting this research, there are a number of limitations which could not be avoided. The first of these limitations relates to the use of self-reported data in the research. Self-reported data cannot be verified or checked easily as it comes from the participants themselves; their attitudes, perceptions and interests are not easily observed or tested. There is also a worry that participants may simply say what they think the researcher wants to hear, or may feel pressured to report the 'right' or 'correct' answer to the questions. However, creating a relaxed and informal interview setting, stressing an interest in the visitors' own opinions, explain that there is no right or wrong answer, and building a rapport with participants over the course of the three interviews, helped to minimise these issues with self-reported data. Participants appeared to be able to express their own opinions and appeared to be unaffected by the presence of the researcher.

Pre-session interviews were conducted with the participants to collect data on their expectations and preconceptions before interacting with the scientist. There is a risk that these pre-session discussions may have influenced the participants' behaviour during the session and their responses in subsequent interviews. Lines of questioning in pre-session interviews may have alerted participants to consider their own perceptions of scientists more than if there had been no pre-session interview, and may have encouraged them to analyse or consider the session more closely as they knew they would be asked about it afterwards. Steps were taken to ensure that these influences were minimal, stressing again that it was participants' own reflections which were of interest and that there would be no 'test' or 'right answers'. Without such pre-session data it is impossible to determine how interactions with scientists may have influenced perceptions, attitudes and understandings.

An alternative approach to that taken in this study would have been to collect pre-session and post-session data with separate samples. Following this approach, where participants would have been asked about their expectations before the session and then a different set of participants asked about their reflections afterwards, would have prevented conclusions being reached about impacts on individuals but conclusions only at the population level. The theoretical notions guiding this work, including identity development, interest development and the development of conceptual ecologies, required analysis on an individual level and, therefore, pre-session and post-session interviews to be conducted with the same individual. Whilst I recognise that the pre-session interviews may have influenced participants to consider more deeply the session and prompt internal reflection about their own perceptions, I argue that the methods used were necessary and the findings justify their use. Indeed, the open nature of the questions would not have revealed a certain hypothesis, and in this way would not have biased participants to give a particular answer over another.

Participants were aware that they would be interviewed two months after the initial museum visit which may have influenced the visitors' and students' behaviours and the impacts reported from the experience of meeting the scientist. For example, participants may have remembered more about the session or may have deliberately followed up the visit in some way, such as looking at the Museum website. This behaviour may have created a bias in the data towards leading to more long-lasting impacts than may have been present in another situation with no follow-up interview.

I argue that the effect of delayed post-session interviews on visitors' and students' behaviours is minimal in my research for a number of reasons. The participants were not aware of the specific questions that would be asked in the delayed post-session interview, despite knowing the broad focus of the research, so they may not have been aware that they would be asked about follow-up activities. Where participants had given their email address I emailed to arrange a suitable time for the follow-up interview, when participants had not left an email address I telephoned and either conducted the interview at that time or arranged a different, more convenient, time with the participants. Some participants indicated that the study had not been at the forefront of their mind, often commenting that they had forgotten that they would be called again, and that the follow-up interview had slipped their mind. This pattern of responses suggests that participants had not been thinking about the questions they might be asked and adapting their behaviour accordingly. Finally, there were visitors and students who stated that they had not carried out any follow-up activities or thought about the session since their visit, as well as those who indicated that they had carried out further engagement activities. There was no benefit or extrinsic motivation driving the participants to give one interview response over another. The presence of a range of responses to delayed post-session questions, negative as well as positive, suggests that participants were being open and were not feeling pressured to report follow-up activities that they had not actually carried out.

Follow-up interviews were conducted by telephone or Skype for the majority of participants, aside from some students who were visited in person at their school. Telephone and Skype interviews have limitations in that the interviewer and interviewee cannot see one another, so no clues can be gained from body language or facial expressions (Rubin & Rubin, 1995). With video calling on Skype some facial expressions and body language can be observed, although not as fully as in a face-to-face interview. Similarly, no hand gestures or movements can be used to emphasise points or help ask a question, so I needed to be particularly clear when asking questions of the participant and always asked for clarification of any ambiguous statements. Despite the limitations of telephone and Skype interviews, using them in the current study enabled delayed post-session responses to be gained from 79% of interviewees, producing an extensive data set from two months after the visit.

Pre-session, post-session and delayed post-session interviews varied in length, due to the number of interview questions and available time (i.e. before the session interviews had to finish before the session began and could not overrun). There was, therefore, different available ‘opportunity to comment’ in each of the three interviews. One criticism of this research may be that differences found by comparing participants’ responses before and after the interactions with scientists may be due to there being more available interview time for participants to say more in the interviews following the interaction. I would argue that the effect of the different lengths of interviews is minimal for the following reasons. Firstly, there is more to discuss following the interaction with the scientist as participants have now experienced something, as opposed to only talking from speculation, expectation and assumption. There are more questions in the post-session and delayed post-session interview schedules for this reason – participants have more to reflect on following the session. The use of longer schedules in the post-session and delayed post-session interviews means that there may not necessarily be more opportunity for participants to comment on any one aspect of the experience, but that more aspects are asked about. The majority of the data analysis is qualitative and, therefore, it is the existence and nature of themes arising which are of interest, as opposed to the occurrences of those themes or the numbers of themes themselves, and in this way the opportunity to comment becomes irrelevant. Furthermore, when data is presented in quantitative form, an effort is made to control for the different lengths of interviews by presenting data as proportions of those occurring in one time period (for example proportions of questions asked in the delayed post-session interview in Figure 19). Thus, although it is recognised that there is the potential for different available opportunities to comment across the different data collection points, I argue that the effects are minimal and that differences observed across time are due to other factors such as the impact of the interaction with the scientist.

Although the research takes a predominantly qualitative approach there are some instances where data have been quantified for illustration and to allow comparison. There are limitations to quantifying qualitative data and risks associated with that including altering the meaning of the data and assigning numerical value to qualitative data. The quantitative interpretations in this research, therefore, have been used only for illustrative purposes: to indicate the prominence of a theme, compare changes in descriptors used, and specify the occurrences of questions on certain topics. The limitations of this process are acknowledged and this has been carried out with caution only where necessary, and triangulating with other data where possible. The illustrations made through numeric representation, however, allow some interesting findings to be explored and are, therefore, valuable in this research.

4.7 Summary

This chapter began by outlining the methodological perspectives of the research and the approaches taken to answering the research questions following the theoretical background of the study. Discussion then moved to the study context and description of the events and participants involved in the research including sampling and recruitment procedures. After detailing the types of data collected to investigate the research questions, discussion turned to data analysis and the frameworks through which the data were scrutinized.

Throughout the chapter there has been discussion about how to ensure that research is of a high quality, that findings are valid and reliable and that the study is conducted in an ethical manner. Three common principles have appeared in this discussion of quality in research. The first of these principles is consistency; uniformity and constancy in application of research methods, sampling of participants, transcription and assigning thematic codes to data. The second recurring principle is that of openness, which is important in thinking about possible results and impacts reported by visitors, being open in questioning and remaining open to alternative interpretations of data. The third and final principle which has reappeared throughout this chapter is about being thorough in carrying out research. Researchers must ensure that they carry out comprehensive interviews, transcription must be thorough with attention to detail, and data analysis must be systematic and in-depth. Following these three main quality criteria, guidance from existing literature, and building on learning from the pilot study, the findings and conclusions reached through this research, and reported in the following chapters, are as valid and reliable as possible.

Chapter 5: Identification *of* scientists

5.1 Introduction

This study contributes to knowledge about museum visitors' and A-level students' perceptions of scientists, and, in particular, how meeting one can influence ideas and attitudes about scientists, their characteristics and work. This chapter explores the data on visitors' and students' identification of scientists, specifically as a result of a face-to-face interaction with a scientist. In examining the identification of scientists I cover participants' expectations and perceptions, and explore changes and trends in these. Impacts on visitors' and students' identification of scientists were complex and multiple; perceptions and expectations did not appear as a consistent set of ideas.

In this chapter I use the notion of a conceptual ecology (diSessa, 2002) to explain the existence of multiple ideas held by students and visitors around scientists. Conceptual ecologies are interconnected ideas around a specific topic. They manifest as the multiple ideas held by an individual about the same subject. I thus discuss the varied conceptual ecologies relating to scientists held by visitors and students and identify the ways in which these conceptual ecologies were influenced by the experience of meeting scientists. DiSessa notes that conceptual ecologies may be made up of contrasting or conflicting ideas simultaneously. Ideas may be drawn on to different extents in different contexts or at different times and are linked and influence one another. In the latter sections of this chapter I discuss my findings which point to the existence of contrasting ideas about scientists.

After an introduction to conceptual ecologies, this chapter starts with a discussion of participants' expectations of scientists, the nature of expectations, sources of these expectations and their complexity. Expectations are then compared with descriptions of scientists, elicited after the event, to explore how meeting scientists influenced visitors' and students' perceptions. I describe ten groupings of the ways in which visitors' perceptions were altered following meeting scientists, and present example individual cases from each grouping. These data provide a sense of the range of conceptual ecologies relating to the identification of scientists that may then change as an impact of meeting them.

This research explores data from Nature Live adult visitors and A-level students attending the behind-the-scenes days; I will use the term ‘visitors’ to refer to those attending Nature Live events and ‘students’ to refer to those attending the A-level days. When referring to all students and visitors taking part in the study I will use the term ‘participant’.

Understanding visitor and student perceptions of scientists is important, as images of scientists will influence how individuals engage with science in the future (Brickhouse *et al.*, 2000; Holland *et al.*, 1998). Seeing scientists as ‘people like me’ is more likely to encourage further engagement with science; if scientists are perceived to be very different from individuals it may discourage engagement and promote the idea that science is done by ‘others’ (Archer *et al.*, 2010). It is arguably important to study the changes in perceptions of scientists before and after events as this can lead to a richer understanding of how interactions may influence participants’ images of scientists which in turn can deepen our understanding of how public engagement with science may be fostered.

5.2 Conceptual ecologies

In terms of visitors’ and students’ identification of scientists and how events might influence perceptions of scientists and science, the findings indicate that participants held multiple ideas about scientists, some of which appeared to conflict. For example, data presented below show that individual participants held perceptions and expectations about scientists which included both the traditional stereotypes (for example, scientists are old) and other ideas (for example, that scientists are young and good communicators).

A conceptual ecology, originally described in physics education, refers to how different ideas about the same concept or phenomenon can coexist, with different conceptions being drawn upon in different contexts and at different times (diSessa, 2002). Conceptual ecology theories were also discussed in section 2.2.1. The idea of coexisting conceptions and the notion that a ‘wrong’ conception cannot be merely replaced by a ‘correct’ conception was argued by Palmer (1999). Indeed, Reeve and Bell (2009) found that students often held contradictory understandings of the concepts ‘healthy’ and ‘unhealthy’. These understandings were not at separate ends of a continuum and the meanings attributed to these concepts were not constant across all contexts.

A conceptual ecology approach can also be used to interpret findings from other studies exploring perceptions of scientists. For example, students in Greece seemed to hold multiple and conflicting views about scientists simultaneously (Christidou, 2010). Students portrayed scientists as traditionally stereotypical in their drawings – for example lab coat, glasses and peculiar hair – and yet also had positive perceptions of scientists expressed as researchers being motivated by altruism and having a passion for knowledge.

A conceptual ecology approach may be an effective theoretical tool in exploring how one set of ideas can be encouraged or drawn upon more frequently than another. The approach may also explain why some stereotypical ideas exist despite exposure to other contradictory experiences. In short, a conceptual ecology approach goes beyond using ideas of cognitive conflict which tend to see learning as replacing one idea with another. Rather it allows for multiple ideas on a subject to be held simultaneously and drawn upon to different extents in different contexts. Cognitive conflict in this case may cause ideas to be more or less favoured within the broader network of ideas, rather than one replacing another. A conceptual ecology approach allows for exploration of a more complex network of ideas and perceptions, which will be relevant when considering broad impacts of learning experiences such as Nature Live.

But, if many conflicting ideas can be accommodated, what is the impact that may be realistically expected from experiences such as meeting scientists? Perhaps the experience of meeting a scientist causes enough cognitive conflict with existing sets of ideas that individuals begin to question one or more sets of expectations about scientists in general. As Reeve and Bell's study showed, expectations arose from a multitude of sources (2009). Clearly, these sources leading to expectations are important – sources with more weight or significance for individuals may cause certain sets of expectations to hold more dominance over others in a conceptual ecology.

In the following two sections I first examine the nature of visitor and student expectations about scientists, followed by the sources of those expectations. I then compare expectations with what is encountered and spoken about after meeting scientists, to assess the impact of meeting scientists on participants' perceptions. The later sections of the chapter explore seemingly contrasting coexisting ideas in more detail.

5.3 Expectations of scientists

Participants' expectations of scientists highlight existing perceptions and reveal preconceived ideas about who scientists are and what they do. Having positive perceptions of scientists and those who engage in science helps individuals to develop their own science identities, identify with the community of science and be encouraged to take part in further science activities (Brickhouse *et al.*, 2000; Holland *et al.*, 1998; Wenger, 1999). This section focuses on the expectations participants had around scientists, the nature of these expectations and the sources they are attributed to.

5.3.1 Manifestation of expectations of scientists

Expectations of scientists arose in two places in the interviews – before participants met scientists in pre-session interviews, and after meeting scientists, in post-session and delayed post-session interviews (retrospective expectations). The retrospective group of expectations was preceded by statements such as 'Well I had been expecting…' or 'I thought they would be more…' and were often made in reference to statements the participants had made about the scientist, after meeting them. For example, students made statements such as the following:

Pre-session expectation:

Interviewer *And what are you expecting the scientists you meet to be like?*

Roger Moore *Of course interesting and not boring, but I guess well-spoken, um, be able to answer all of our questions.* (AL-G group, pre-session interview)

Retrospective expectation:

Walrus *I was surprised to see how young some of them were, just walking around seeing all the scientists, some of them were a lot younger than I thought they would be. I was sort of expecting there to be lots of bearded men with white coats.* (AL-D group, delayed post-session interview)

During each of the three interviews, visitors and students were asked to describe the Museum scientist. This series of questions generated a number of descriptors – adjectives or descriptive phrases – which participants used to describe their expectations and experiences. For more detail on the methods of analysing the descriptors, see section 4.5.2. Individual descriptors were clustered into categories to allow for clear comparison. A full list of descriptors in each category was provided in Table 6. Table 8 summarises which descriptor categories were mentioned by participants within each set of expectations – pre-session and retrospective.

Table 8. Frequency of participants holding expectations about scientists in each descriptor category. (Some individuals mentioned expectations under more than one descriptor category).

Descriptor category	Nature Live visitors (n = 81)		A-level students (n = 38)	
	Pre-session expectations	Retrospective expectations	Pre-session expectations	Retrospective expectations
Approachable and nice	5	0	3	0
Confident and good communicator	13	2	7	0
Experienced and knowledgeable	21	1	12	0
Funny and entertaining	5	0	0	0
Helping to learn	12	0	3	0
Interesting and engaging	12	0	7	0
Normal people and against the stereotype	22	0	1	0
Not engaging and bad communicator	1	1	2	0
Passionate and enthusiastic	18	0	3	0
Relaxed and informal	3	0	1	0
Stereotypical scientist	12	8	0	12

The nature of the participants' retrospective expectations was examined in more detail to establish whether they reflected the expectations revealed by participants in the pre-session interview or were different to those revealed before meeting scientists. Twelve students (of the total 38) mentioned expectations retrospectively; all of their retrospective expectations were relating to stereotypical characteristics of scientists. For example:

Alice *I expected someone all, like, coated up, in like lab coats and that.* (AL-A group, post-session interview)

Eleven visitors (of the total 81) mentioned expectations retrospectively. Of those 11, eight individuals held stereotypical expectations about scientists retrospectively. For example:

Judith *He certainly wasn't the nutty professor I expected him to be!* (NL-X, post-session interview)

For the other three visitors, two held retrospective expectations about the scientists being 'confident and a good communicator'. One of those visitors also reported retrospectively having expected the scientist to be an 'experienced and knowledgeable expert'. Another visitor had been expecting the scientist to be 'not engaging and a bad communicator'.

In pre-session interviews, visitors and students had revealed other expectations. Participants held a wide range of ideas about scientists before they met them; visitors' pre-session expectations fall under 10 of the 11 descriptor groupings and students' under 9 of the 11. Retrospective expectations fall under 4 of the 11 descriptor categories. Pre-session expectations were more positive than the retrospective expectations, the majority of which reflected the stereotypical scientist features.

These findings about expectations suggest that individuals may have multiple ideas about scientists which they employ to form perceptions and expectations. The existence of multiple sets of expectations could explain the differences between the pre-session and retrospective expectations seen in Table 8 and would fit with the conceptual ecology model (diSessa, 2002; Reeve & Bell, 2009), discussed above. This complexity of perceptions could explain the tenacity of particular attitudes (including unfounded stereotypical views) in spite of the Nature Live experience. Visitors might have had two or more sets of expectations which they drew from at different times and in different contexts: one group was used when making pre-session expectations and another set of ideas was used to articulate their retrospective expectations.

To illustrate the differences between pre-session expectations and retrospective expectations, I use Carol (NL-B) as an example. Carol attended a Nature Live session about bees, a subject she was particularly interested in although had not expected to attend such a session and meet a scientist as part of her visit that day. In her pre-session interview Carol initially spoke about expecting the scientist to be dedicated and enthusiastic, explaining that as they are doing such a lot of detailed research they must be passionate about the subject:

Carol *I would think it's quite an exciting time, I'm also they must spend ever such a lot of hours, and hours, just looking at something* […]*you know somebody spending 40 years looking at a wasp. That's dedication isn't it! But if they didn't do that, if they didn't have that kind of enthusiasm, we'd lose it* [nature]. (Pre-session interview).

However, after the session Carol eludes to the more stereotypical expectations she had about the scientist she met:

Carol *You expect a scientist to be a little chap don't you, with greying hair and a little bit eccentric, and probably little tiny glasses on the end of his nose.* (Post-session interview)

In her delayed post-session interview Carol again mentions the retrospective expectation she had about the scientist having some of the traditional stereotypical characteristics:

Carol *I was expecting somebody to be a bit more wooly than he was, you know Einstein.* (Delayed post-session interview)

Carol's interview responses illustrate how the nature and content of an individuals' expectations can be different depending on when they are mentioned – before the session or retrospectively.

The retrospective expectations arising in the post-session and delayed post-session interviews were more negative than those expressed before the session. One explanation is that participants may have felt impolite in making negative comments about the scientists they were about to meet and thus only admitted to the more negative expectations such as scientists being eccentric and looking like Einstein once they had met them and had seen that these non-voiced anticipations had not been met. Another related possibility is that participants might have held back on things that they thought the interviewer would not want to hear. Although these are possible scenarios, they are, however, unlikely to be the main causes of the difference between the two types of expectations. Participants were reminded that all comments were confidential and that I was interested in their honest opinions. Participants also revealed other negative expectations before meeting scientists, for example about scientists being boring or distracted. The findings suggest, therefore, that participants were being open and honest in responding to the interview questions and were not withholding negative comments. Differences between the categories of descriptors used in both sets of expectations, therefore, are arguably due to other factors reflecting participants' conceptual ecologies.

As the retrospective expectations are revealed following the session another explanation for their difference in composition compared to the pre-session expectations may be that the retrospective expectations have been influenced by the experience of meeting scientists itself. Pre-session expectations are uncontaminated by the experience. It is still possible that the experience triggers visitors to draw from a different set of ideas within a conceptual ecology, as illustrated in the case of Carol above. If the aim, however, is to compare expectations before any effect of the experience itself, to descriptions provided afterwards, only those expectations revealed in the pre-session interviews should be used. Thus, when comparing descriptors used across time periods later in the thesis to determine the effect of the experience of meeting scientists I use pre-session expectations only when I refer to expectations of individuals.

5.3.2 Sources of student expectations about scientists

The reasoning behind the students' expectations emerged in their interview responses. Data on sources of expectations are important as they indicate from where perceptions have arisen and the sources that are most influential in shaping attitudes and images. By identifying the sources of students' perceptions, it is possible to explore how their ideas might be altered. These sources of expectations were attributed to both pre-session and retrospective expectations. The Nature Live visitors, however, did not reveal the sources of their expectations in the same way. Three sources of student expectations of scientists were identified:

i) Stereotypes associated with media images;
ii) Attitudes towards the subjects that the scientist was studying; and,
iii) Prior experience of meeting scientists.

i) Stereotypes associated with media images of scientists

Eight students mentioned that their ideas about what to expect from the scientists came from television images or well-known stereotypes – by, for example, saying: 'How you see scientists normally', 'How you think of scientists'. Hermione (AL-C group) thought that the scientist she met at the Museum was more interesting than she was expecting – basing her expectations on

TV scientists she had seen who she described as ‘crazy’, ‘mad’ and ‘geeks’. These sources of expectations about scientists were not as specific and easy to pinpoint as the other two sources of expectations, often described by participants in more general terms, but the influence of the media in shaping perceptions of scientists has been studied elsewhere with similar findings. For example, television and films were the most cited source for drawings of scientists in a study with 12-13 year-old students (Steinke *et al.*, 2007). Such perceptions may, therefore, be more difficult to influence but their existence highlights the complex nature of how and where expectations are formed.

ii) Attitudes towards the subject the scientist was studying

Four students made assumptions about the people they were going to meet based on the subjects the scientist specialised in. Students transferred their attitudes towards the particular subject onto the scientists, influencing what they expected the scientists to be like. For example, Ahmed (AL-I group) formed certain expectations about a researcher he was going to meet based on his attitude towards botany, which he thought was ‘boring’. In the interviews, Ahmed expressed his surprise that the scientist was not boring, and described him as a ‘normal person’.

iii) Prior experiences meeting scientists

Three students reported having met researchers previously and they used this experience and their attitudes towards the scientists they had met to form expectations about the people they were going to meet at the Museum. For example, Seamus (AL-F group) spoke about how he had met a science professor at a university interview whom he found boring and he thought they did not enjoy their job. Seamus, therefore, described his surprise at meeting a scientist who was engaging, enthusiastic and who clearly enjoyed what he worked on.

This section explored the nature and sources of expectations around scientists. What follows is a discussion of whether those expectations were confirmed or challenged by the experience of meeting scientists, and how participants’ identification of scientists was developed as a result.

5.4 Identification of scientists

Interviews indicated that there were changes in participants' perceptions of scientists following meetings. Perceptions of scientists were explored by analysing the descriptors which were used by visitors when describing their expectations or experiences of scientists.

To analyse what behaviours were occurring in terms of visitors' conceptual ecologies around scientists, a decision coding tree was constructed, Figure 5. This decision coding tree is similar to an outcome space used in studies in science education (see section 4.5.2 for a description of the analytic process, and for examples of outcome spaces see Sin, 2010; Yasri and Mancy, 2014). The decision coding tree aided the identification of ten groups of individuals who shared similar types of behaviour relating to their ideas about scientists as a result of meeting them. These ten groups describe the patterns and types of behaviours observed in relation to *changes* in perceptions, rather than categorising the specific perceptions held.

The coding tree is shown in Figure 5, with the ten groupings of behaviours highlighted (A – J). The coding tree is constructed using five behaviour types to describe changes in visitors' perceptions under each descriptor category, leading to ten groups which are formed of combinations of these behaviour types. In this section when I speak about certain ideas or perceptions, I am referring to participants using descriptors under certain descriptor categories (for example the scientist is knowledgeable or friendly). First I present the definitions of the terms used to describe the types of behaviours possible in regards to perceptions as a result of meeting scientists. For example, perceptions may emerge (a new perception may form) or be confirmed. Behaviour groups then consist of visitors whose perceptions undergo multiple types of behaviours occurring at once (for example, the 'Emerge; confirm' group's members experienced an 'emergence' in their ideas *as well as* 'confirmation' of other ideas).

Behaviour types:

- Confirmation: visitors had expectations in a certain descriptor category about scientists which were also seen in the interview following the meeting;
- Non-confirmation: ideas in a certain descriptor category which were reported before meeting scientists were not present in later interviews;
- Emerging: expectations in a certain descriptor category were not previously reported but were present in later interviews;

- Reverting: visitors initially had ideas in a certain descriptor category which they then presented in the delayed post-session interview, although they were not seen in the post-session interview;
- Change: some ideas which were reported in pre-session interviews did not reappear in subsequent interviews, but simultaneously new ideas not present in pre-session interviews were present in interviews following meeting the scientist;

Figure 5. Decision coding tree: Used in coding individuals according to types of behaviours relating to changes in perceptions of scientists.

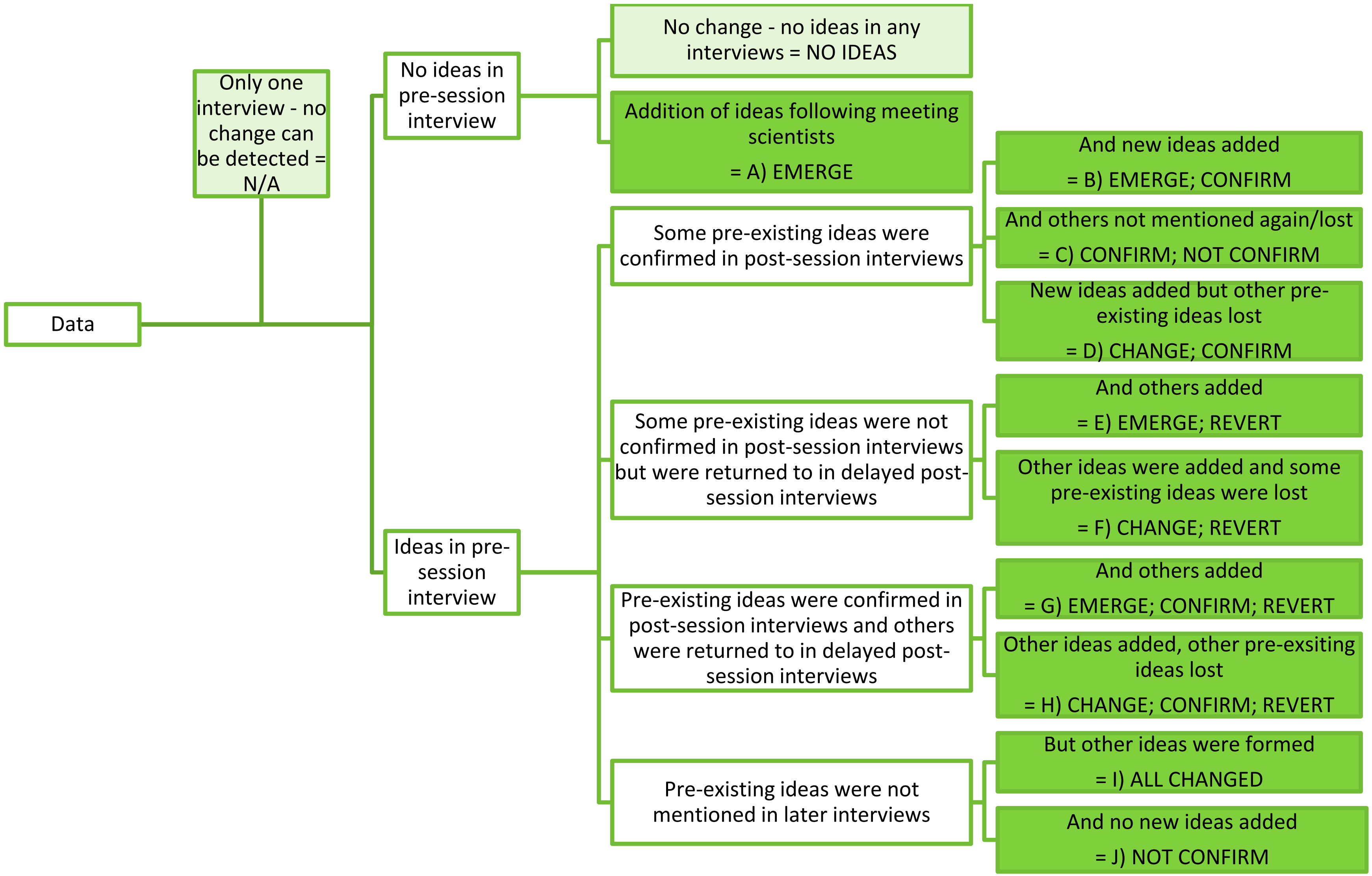


Figure 5 illustrates the grouping of individuals according to the types of behaviour they exhibit relating to their perceptions following meeting scientists. There are some subtle but important differences between the groups which are reflected in the terminology used. Particularly, in groups with ‘change’, ideas are both gained and lost; groups with ‘emerge’ have ideas gained only. Groups with ‘confirm’ indicate where pre-existing ideas have been instantly confirmed, whereas groups with ‘revert’ indicate that pre-existing ideas were not immediately confirmed, but were later returned to in the delayed post-session interview. Behaviour groups are described in more detail in Table 9 which includes frequencies and names of key individuals for each group.

5.4.1 Visitors’ identification of scientists

Nature Live visitors could be organised into nine of the ten behaviour groupings, A-level students (see section 5.4.2) could be grouped into eight of the ten behaviour groupings. For 75 out of 81 Nature Live visitors some change was detectable in the perceptions held of scientists following an interaction. Three individuals, however, were only interviewed once and, therefore, no change could be examined over time and another three individuals did not report any ideas about scientists before or at any point after meeting a scientist. The lack of vocalising of perceptions of scientists may have been due to a number of reasons. For example, the visitor might not have been able to articulate their perceptions or could not have thought of any at that time, or the partner or family member they were visiting with may have spoken more and they just agreed or let them speak, not vocalising any ideas of their own. Nonetheless, the lack of existence of any ideas at all about scientists in any time period was unusual, other visitors mentioned ideas about scientists in a mean of five descriptor categories over all interviews.

Table 9. Changes in perceptions of scientists: Groupings according to the sorts of behaviours exhibited around perceptions of scientists following meeting a scientist.

Behaviour groups	Description	Number of visitors	Number of students	Example case (visitors)
A) Emerge	Individuals did not hold any ideas about scientists before meeting them, and in post-session and delayed post-session interviews reported new ideas.	12	9	Laurie (NL-Zq)
B) Emerge; confirm	Individuals reported ideas about scientists in pre-session interviews which were confirmed in post-session interviews, along with the addition of new ideas about scientists in post-session/delayed post-session interviews.	15	2	Anne (NL-D)
C) Confirm; not confirm	Individuals reported ideas about the scientists in the pre-session interview, some of which were confirmed, others were not confirmed and did not appear in post-session/delayed post-session interviews.	2	0	Patrick (NL-Zz)
D) Change; confirm	Individuals had ideas about the scientist before the session, some of which were confirmed in post-session interviews and some of which were not. Participants also formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.	15	6	Serafina (NL-V)
E) Emerge; revert	Individuals reported ideas about scientists in pre-session interviews	4	3	Kate (NL-L)

		which were not mentioned in post-session interviews but were returned to in delayed post-session interviews. Participants also formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.			
F)	**Change; revert**	Individuals had ideas about the scientist before, none were mentioned in post-session interviews, some were returned to in delayed post-session interviews and some were not. Participants also formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.	3	2	Jasmine (NL-Zo)
G)	**Emerge; confirm; revert**	Individuals had ideas about the scientist before meeting them, some of which were confirmed and mentioned in post-session interviews, whereas some were not mentioned in post-session interviews but were returned to in delayed post-session interviews. Participants also formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.	4	0	Amelia (NL-Zk)
H)	**Change; confirm; revert**	Individuals had ideas about the scientist before, some of which were confirmed in post-session interviews, some of which were returned to in delayed post-session interviews and some of which were not. Participants	5	1	Pat (NL-P)

		also formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.			
I)	**All change**	Participants had some ideas about scientists before meeting them, none of which were confirmed or returned to. Participants formed new ideas about scientists which were mentioned in post-session and delayed post-session interviews.	15	4	James N (NL-Zx)
J)	**Not confirmed**	Participants had some ideas about scientists before meeting them but no ideas were discussed after meeting the scientist. The pre-existing ideas were not returned to, nor new ideas formed.	0	1	*See section 5.4.3 for discussion*

Key individuals were identified in Table 9 because they were typical of the category and because they clearly exemplified the behaviours in terms of changes in perceptions of scientists. The key individuals here are all visitors, students are discussed in section 5.4.3. What follows is a discussion of each category and the key individual for that category in order to demonstrate the diverse ways in which the scientists had an impact on individual visitors' identification of scientists.

A) Emerge (12 visitors)

Some visitors did not reveal any ideas about scientists in pre-session interviews but developed ideas following meeting them. These emerging ideas might have been present in post-session and/or delayed post-session interviews.

Laurie (NL-Zq) is an example of someone who showed an emergence in perceptions following meeting a scientist. Examples of the descriptors she used across all three interviews to speak about her expectations and experiences of the scientists are shown in Figure 6[11]. Laurie visited the Museum with her husband and they attended a session on fossils and the Cambrian explosion. Laurie did not mention any pre-existing ideas about scientists when asked in the pre-session interview. However, she later spoke of the scientist being confident and a good communicator, as well as experienced and knowledgeable, ideas which were sustained and mentioned again in the delayed post-session interview. Laurie also thought that the scientist had been passionate and enthusiastic; however no comment within this description was made two months after the visit. In sum some perceptions initially emerged and some emerged later and were longer-lasting.

[11] Presented in Figures in this section are examples of individuals showing every descriptor category they mentioned in each interview, together with data to provide illustrative examples of these descriptor categories in the form of quotes. These quotes may be full sentences or comments but may just be individual words which participants used to describe scientists.

Figure 6. Laurie (NL-Zq) Example case of 'Emerge' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
	Confident and good communicator	**Confident and good communicator**
No comment made in this descriptor category	*I guess she had to prepare for it, had to think what am I going to say to lay people who know nothing about what I do.*	*I can really appreciate how difficult that is because my job when I explain to people in industry about what my company does communicating to people who have no idea about it – I think she did a really excellent job.*
	Experienced and knowledgeable	**Experienced and knowledgeable**
No comment made in this descriptor category	*She is doing a post-doc, often people do that and stay in research*	*She had just finished her PhD and she was doing a post-doc research*
	Passionate and enthusiastic	
No comment made in this descriptor category	*She was very passionate about it, and that is infectious*	No comment made in this descriptor category
		Normal people and against the stereotype
No comment made in this descriptor category	No comment made in this descriptor category	*Young woman*

B) Emerge; confirm (15 visitors)

Visitors in the 'emerge; confirm' category had their pre-existing ideas confirmed and gained new ideas following meeting the scientists. They differ from visitors in the other groups in that all of their pre-existing perceptions of scientists were confirmed in the post-session interview, although new ideas may also appear in post-session or delayed post-session interviews. Thus the categorisation is 'emerge; confirm'.

Anne (NL-D) was an example of someone who displayed ‘emerge; confirm’ behaviour in regards to her perceptions of scientists, Figure 7. Anne visited the Museum with her friend Joan and they came to see one of the Museum entomologists speak about moths. Anne did not describe herself as a scientist. Anne’s idea that scientists might help her to learn something was confirmed and sustained throughout all of the interviews. She also was expecting the scientist to be passionate and enthusiastic, something which was confirmed in the post-session interview. Anne developed new ideas about the scientist following the session, some of which were developed in the post-session interview and sustained to the delayed post-session interview (for example she mentioned that the scientist was approachable in the post-session interview and again mentioned how nice he had been in the delayed post-session interview). Other ideas were developed later, following the visit, for example, the idea that the scientist was relaxed and informal, and confident, and good at communicating. With descriptors spanning seven of the descriptor categories, it is cases like Anne’s which demonstrate the rich and multifaceted nature of perceptions of scientists held by individuals.

Figure 7. Anne (NL-D) Example case of 'Emerge; confirm' behaviours

Pre-session interview	Post-session interview	Delayed post-session interview
Helping to learn	**Helping to learn**	**Helping to learn**
Informative	*Very informative*	*You know, he answered all our questions.*
Passionate and enthusiastic	**Passionate and enthusiastic**	
Inquisitive	*It seems he's interested enough to take it up as a hobby as well.*	No comment made in this descriptor category
	Approachable and nice	**Approachable and nice**
No comment made in this descriptor category	*No bother about the questions.*	*I thought no he was lovely. He was really nice.*
	Normal people and against the stereotype	**Normal people and against the stereotype**
No comment made in this descriptor category	*Just a normal chappy.*	*He was like, one of the, one of the people.*
	Experienced and knowledgeable	
No comment made in this descriptor category	*A wonderful achievement when he actually got it* [data he had been studying and working towards].	No comment made in this descriptor category
		Relaxed and informal
No comment made in this descriptor category	No comment made in this descriptor category	*He was quite natural.*
		Confident and good communicator
No comment made in this descriptor category	No comment made in this descriptor category	*We could understand him, he talked, you know not in gobbledygook.*

C) Confirm; not confirm (2 visitors)

Whereas most of the groups included a broadening of ideas about scientists and the addition of new ideas or confirming of existing ideas, there were two visitors whose range of ideas narrowed after the session. Visitors in the 'confirm; not confirm' category had some of their pre-existing ideas confirmed and spoke of these in post-session interviews, but some ideas appeared not to be confirmed and thus were not mentioned following meeting scientists. For both visitors in the 'confirm; not confirm' category, no delayed post-session interview could be conducted, so it cannot be concluded that ideas did not return two months after the visit or that new ideas developed within this period. However, with the data available, these visitors seemed to become narrower in their perceptions of scientists following meeting them.

Patrick (NL-Zz) was an example of a visitor from the 'confirm; not confirm' category, Figure 8. Patrick visited the Museum with his family including his wife and two children, and attended a Nature Live session about fossils. Patrick said that he did not have a scientific background and did not work in a science field.

Figure 8. Patrick (NL-Zz) Example case of 'Confirm; not confirm' behaviours.

Pre-session interview	Post-session interview
Experienced and knowledgeable	**Experienced and knowledgeable**
I assume they are just carrying on their research, and doing their PhD.	*It's good to hear from someone who is actually doing the work.*
Interesting and engaging	**Interesting and engaging**
Interesting	*Lively*
Normal people and against the stereotype	
Young	No comment made in this descriptor category

D) Change; confirm (15 visitors)

Visitors within the 'change; confirm' grouping showed some perceptions which were confirmed from pre-session to post-session interviews. Other pre-existing perceptions, however, were not confirmed or returned to, and new ideas appeared following meeting the scientist. This group differs from the 'all change' group in that some of their existing ideas were confirmed by their experiences of meeting scientists.

Serafina (NL-V) is an example of someone whose perceptions of scientists fell within the ‘change; confirm’ category. Her perceptions and the changes in her ideas over time are illustrated in Figure 9. Serafina attended the event with her daughter and described herself as a ‘*computer geek rather than a science one*’ (pre-session interview), as she worked with computers and IT. Serafina was expecting the scientist to be both stereotypical in some aspects and not in others; she had a duality within her perceptions. Duality and contrasts in perceptions of scientists is discussed further below (section 5.6). Serafina developed some new ideas about scientists following the meeting – that they helped the audience to learn, and were interesting and engaging – and these ideas were sustained at least until the delayed post-session interview.

Figure 9. Serafina (NL-V) Example case of ‘Change; confirm’ behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Stereotypical scientist		
Ross from Friends!...Geeky, but not too geeky.	No comment made in this descriptor category	No comment made in this descriptor category
Normal people and against the stereotype	**Normal people and against the stereotype**	
I think they are just normal people, just more interested in one thing than another.	*Thank God he wasn’t wearing glasses and a white coat!*	No comment made in this descriptor category
	Helping to learn	**Helping to learn**
No comment made in this descriptor category	*Very informative and you knew what he was talking about.*	*He was very informative, not over-powering, so he was very simple in his explanation.*
	Interesting and engaging	**Interesting and engaging**
No comment made in this descriptor category	[He] *made it interesting.*	*He was interesting and exciting.*
		Experienced and knowledgeable
No comment made in this descriptor category	No comment made in this descriptor category	*Someone who knew what they were talking about.*
		Funny and entertaining
No comment made in this descriptor category	No comment made in this descriptor category	*Also making it fun for the little kids.*

E) Emerge; revert (4 visitors)

In this category, visitors developed new ideas, and where they had pre-existing ideas these were returned to in delayed post-session interviews but not confirmed in post-session interviews. This category differs from the ‘emerge’ category because of the existence of ideas in pre-session interviews which were later returned to in delayed post-session interviews.

Kate (NL-L) showed ‘emerge; revert’ behaviours regarding her perceptions of scientists (Figure 10). Kate is a primary school teacher and had studied psychology at university. She visited the

Museum with her partner, and was keen to see the session on volcanoes because she was teaching that topic in the coming months. Kate had ideas about scientists before the session which fell into two descriptor categories: ‘interesting and engaging’ and ‘experienced and knowledgeable’. These ideas were not mentioned immediately after the session, but were returned to in the delayed post-session interview. Additionally, new ideas were developed following meeting the scientist, including some which were sustained until the delayed post-session interview (for example the scientist being passionate and enthusiastic) and some which were shorter-lived (for example the scientist being funny and entertaining).

Figure 10. Kate (NL-L) Example case of 'Emerge; revert' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Interesting and engaging		**Interesting and engaging**
I'm expecting a really interesting talk.	No comment made in this descriptor category	*The most interesting thing was him and his experience there.*
Experienced and knowledgeable		**Experienced and knowledgeable**
You know this is what someone does for a living, and they're here, while we're here.	No comment made in this descriptor category	*His area is obviously a lot higher than my level.*
	Helping to learn	**Helping to learn**
No comment made in this descriptor category	*His talk today was very accessible.*	*Used a demonstration with a stick to explain what was going on... he gave us lots of information.*
	Passionate and enthusiastic	**Passionate and enthusiastic**
No comment made in this descriptor category	*You could tell he's really passionate about what he's doing.*	*He was very interested in his own work, and his passion, he was very passionate about it.*
	Approachable and nice	**Approachable and nice**
No comment made in this descriptor category	*Very approachable I think*	*Very chatty*
	Confident and good communicator	**Confident and good communicator**
No comment made in this descriptor category	*I thought he was really good at presenting what he does.*	*he was a very good speaker as well.*
	Funny and entertaining	
No comment made in this descriptor category	*It wasn't all very straight-laced, he made it fun.*	No comment made in this descriptor category
	Normal people and against the stereotype	

No comment made in this descriptor category	*Really open about his experiences and how it made him feel.*	No comment made in this descriptor category

F) Change; revert (3 visitors)

For some visitors, new ideas were added and some pre-existing ideas were lost following meeting scientists, much like the ‘all change’ category below. The difference between the ‘all change’ category and the ‘change; revert’ visitors was that for the ‘change; revert’ visitors, some pre-existing ideas *did* reappear in later interviews – they were present in the delayed post-session interviews.

Jasmine (NL-Zo) is an example of a visitor who displayed ‘change; revert’ behaviours in relation to her perceptions of scientists (Figure 11). Jasmine attended the Museum with her mother and saw a scientist speak about volcanic islands. Some of Jasmine’s initial ideas about the scientist were returned to in later discussions, for example expecting the scientist to be experienced and knowledgeable. However, ideas from two categories of descriptors were not confirmed or returned to: the idea that scientists might be funny and entertaining, and be like the stereotypical image of scientists. Jasmine gained new ideas about the scientist following the session, including thinking that they were passionate and enthusiastic, an idea which was sustained to the delayed post-session interview.

Figure 11. Jasmine (NL-Zo) Example case of 'Change; revert' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Experienced and knowledgeable		**Experienced and knowledgeable**
Professional	No comment made in this descriptor category	*Very knowledgeable about that kind of thing.*
Funny and entertaining		
Probably fun	No comment made in this descriptor category	No comment made in this descriptor category
Stereotypical scientist		
Mad scientist!	No comment made in this descriptor category	No comment made in this descriptor category
	Passionate and enthusiastic	**Passionate and enthusiastic**
No comment made in this descriptor category	*Very passionate*	*Quite passionate about it too.*
		Helping to learn
No comment made in this descriptor category	No comment made in this descriptor category	*Nice to have someone explain things to you that you don't understand.*
		Interesting and engaging
No comment made in this descriptor category	No comment made in this descriptor category	*Interesting*

G) Emerge; confirm; revert (4 visitors)

Visitors in the 'emerge; confirm; revert group' had some existing ideas before meeting scientists which were mentioned in later interviews. Some ideas were immediately confirmed in post-session interviews, whereas some did not appear in post-session interviews but were returned to in delayed post-session interviews. Additionally, new ideas were formed following the session.

Amelia (NL-Zk) is an example of a visitor who displayed 'emerge; confirm; revert' behaviour in relation to her perceptions about scientists (Figure 12). Amelia attended a Nature Live event about bugs with her family and did not describe herself as a scientist. Amelia had some of her pre-existing ideas about scientists confirmed by the experience (for example that they were experienced and knowledgeable) and others, although not immediately confirmed, were returned to later (for example that they were ‘normal people’ and not like the stereotypical image of scientists). Other new ideas formed following meeting the scientist; some were sustained in delayed post-session interviews, some were not, and others did not appear until the delayed post-session interviews themselves.

Figure 12. Amelia (NL-Zk) Example case of 'Emerge; confirm; revert' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Experienced and knowledgeable	**Experienced and knowledgeable**	
Very knowledgeable	*She answered every question didn't she? So she obviously knew her stuff.*	No comment made in this descriptor category
Normal people and against the stereotype		**Normal people and against the stereotype**
Or even she! [In response to husband calling scientist 'he' before knowing whether they were male or female].	No comment made in this descriptor category	*So to have, especially women there as well.*
	Approachable and nice	**Approachable and nice**
No comment made in this descriptor category	*She wasn't scary was she? You felt you could ask her questions.*	*And they were very approachable – at the end when the girls went up to speak to them they were very approachable.*
	Interesting and engaging	
No comment made in this descriptor category	*She was impressive wasn't she?*	No comment made in this descriptor category
	Relaxed and informal	
No comment made in this descriptor category	*Did you think she was cool? The bug lady.*	No comment made in this descriptor category
		Helping to learn
No comment made in this descriptor category	No comment made in this descriptor category	*They explained things in layman's terms, they didn't seem to go into any intricacies, they explained the basics... in ways they* [her children] *could understand.*

H) Change; confirm; revert (5 visitors)

Some visitors' ideas underwent a variety of changes – new ideas arose, some pre-existing ideas were lost, and other pre-existing ideas reappeared in later interviews – either confirmed in post-session interviews or returned to in delayed post-session interviews. These visitors were termed the 'change, confirm and revert' group, and they differ from the 'all change' and 'change and confirm' groups because they also had pre-session ideas which did not appear in post-session interviews but did return in delayed post-session interviews. The 'change; confirm; revert' category also differs from the 'emerge; confirm; revert' group as some of the visitors' pre-existing ideas were lost, along with the addition of new ideas; in groups with 'change', pre-existing ideas are both gained and lost, groups with 'emerge' have ideas gained only.

An example of one of the 'change; confirm; revert' visitors was Pat (NL-P), illustrated in Figure 13. Pat visited the Museum with his partner; they had attended a Nature Live event a few days before when visiting with their children, and had decided to return to the Museum to explore other areas and see a new session. Pat said that he did not have a scientific background or currently work in science, but he was interested in science.

Figure 13. Pat (NL-P) Example case of 'Change; confirm; revert' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Experienced and knowledgeable	**Experienced and knowledgeable**	**Experienced and knowledgeable**
Full of knowledge	*The people who are bringing you this information* [that you see in exhibitions].	*Knowledgeable and knows more about certain things.*
Helping to learn		**Helping to learn**
Being a good teacher	No comment made in this descriptor category	*If you had a question you could ask and she would give you a good answer.*
Interesting and engaging		
Grab your attention	No comment made in this descriptor category	No comment made in this descriptor category
Normal people and against the stereotype		
Just anyone I guess	No comment made in this descriptor category	No comment made in this descriptor category
	Funny and entertaining	**Funny and entertaining**
No comment made in this descriptor category	*Bit of humour as well*	*A bit of humour thrown into the mix.*
	Passionate and enthusiastic	**Passionate and enthusiastic**
No comment made in this descriptor category	*Someone who is passionate about what they believe in.*	*She was really good, positive.*
	Relaxed and informal	**Relaxed and informal**
No comment made in this descriptor category	*Relaxed manner*	*Felt relaxed*
	Stereotypical scientist	
No comment made in this descriptor category	*The modern research that goes on, a lot of it is behind closed doors.*	No comment made in this descriptor category
		Approachable and nice
No comment made in this	No comment made in this	*Open and friendly, yeah you*

descriptor category	descriptor category	*weren't made to feel, like, inferior or anything.*
		Confident and good communicator
No comment made in this descriptor category	No comment made in this descriptor category	*She was confident*

I) All change (15 visitors)

For visitors in this category, no pre-existing ideas were confirmed or reverted back to following meeting scientists; all ideas previously held disappeared and visitors developed totally new ones. Some of these new ideas may have been sustained to the delayed post-session interviews and some of them may have been short-lived. This category represents visitors who underwent a total change in their perceptions of scientists following their meeting.

One example of such a visitor displaying 'all change' behaviour was James N (NL-Zx). The ideas about scientists that he presented are shown in Figure 14. James N was visiting the Museum with his two daughters and attended a session on edible insects. He had studied for a science degree but did not work in science at the time. His expectations about stereotypical scientist descriptors did not reappear in the post-session or delayed post-session interviews, where new perceptions were revealed around the scientist being a 'normal person' and relaxed and informal.

Figure 14. James N (NL-Zx) Example case of 'All change' behaviours.

Pre-session interview	Post-session interview	Delayed post-session interview
Stereotypical scientist		
Geeky	No comment made in this descriptor category	No comment made in this descriptor category
	Normal people and against the stereotype	**Normal people and against the stereotype**
No comment made in this descriptor category	[He was] *down to earth.*	*The scientist was just a normal bloke.*
	Relaxed and informal	**Relaxed and informal**
No comment made in this descriptor category	*Easy-going, relaxed*	*Just sat there and chatted about what he had eaten and what could be eaten.*

5.4.2 Summary of changes in visitors' identification of scientists

This section has described nine ways in which visitors' perceptions were changed or not as a result of meeting scientists during Nature Live events. The final, tenth, behaviour group relating to perceptions is discussed below with the student data. These behaviour groups describe 75 out of the 81 visitors interviewed and refer to the types of behaviours visitors exhibited in relation to their perceptions of scientists at three time periods (pre-session, post-session, delayed post-session).

Each individual visitor displayed a unique set of ideas before meeting scientists and as changes to those ideas were varied, the combinations of changes to perceptions were diverse. This diversity of ideas, and combinations of changes to ideas, highlights the difficulties in defining the 'impact' of experiences such as museum experiences, the individuality of visitors' 'starting points' and the multiple ways these might be affected by one experience over time.

The groups with the most visitors include 'emerge; confirm', 'change; confirm' and 'all change' (15 visitors each). The next most populated group was 'emerge' (12 visitors). The following groups trail someway behind in terms of frequency of visitors, with 'change; confirm; revert' (5 visitors), 'emerge; confirm; revert' and 'emerge; revert' (4 visitors each), 'change; revert' (3 visitors) and 'confirm; not confirm' (2 visitors). The distribution of individuals across these groupings suggests that visitors were more likely to change their perceptions of scientists following meeting them, gaining new ideas and changing existing ideas. In addition, the findings suggest that visitors are more likely to increase the breadth of their ideas than decrease it following meeting scientists. In sum, it would appear that meeting scientists may lead to visitors holding more diverse, well-formed and broader perceptions of scientists.

5.4.3 Students' identification of scientists

The data and groupings described in the previous section came from the interviews with Nature Live visitors. A-level students followed a similar pattern in terms of the types of behaviours they showed in relation to their perceptions of scientists, see Table 9. The categorisation describes 28 students, the other ten students could not be described using the behaviour groups as they did not take part in pre-session interviews and, therefore, changes in perceptions from expectations could not be measured.

The behaviour group 'not confirmed' occurred only once in the whole data set, describing an A-level student but no Nature Live visitors. The student in this category (Jabomba, AL-I) was very quiet in interviews and mentioned perceptions of scientists only once (that scientists would be approachable and friendly), in the pre-session interview, despite encouragement to contribute more responses later.

For illustration, one student example case is presented, from the most frequently populated group: 'Emerge'. Betty Boop was in group AL-C, and met scientists who spoke to her about chocolate and botany, and then parasites which live on salmon, Figure 15.

Figure 15. Betty Boop (AL-C) Example case of 'Emerge' behaviours.

Pre-session interview	Post-session interviews	Delayed post-session interview
	Experienced and knowledgeable	**Experienced and knowledgeable**
No comment made in this descriptor category	*Know a lot about it* [their subject].	*And she was saying interesting facts that I don't think many people know… She has, like, a degree in whatever she does.*
	Passionate and enthusiastic	**Passionate and enthusiastic**
No comment made in this descriptor category	*They have passions*	*They seemed passionate about what they were doing.*
		Helping to learn
No comment made in this descriptor category	No comment made in this descriptor category	*And like we understood everything she was saying.*
		Interesting and engaging
No comment made in this descriptor category	No comment made in this descriptor category	*It was just interesting, we never knew that much about chocolate and salmon.*

Although the broad pattern of the types of behaviours exhibited in relation to perceptions of scientists is similar, there are some differences between the A-level group and the Nature Live visitors. A-level students were interviewed in small groups as this facilitated discussion and interaction and was more relaxed and in-keeping with the rest of their visit. As a result of the data collection methods, however, individuals may have spoken slightly less about their perceptions than might have been the case for individual interviews. Not every student would answer every question, despite prompting, and some students would talk extensively to answer one question whereas others would nod in agreement or give short answers such as 'Yes, the same'.

A-level students as a population described their expectations and experiences of scientists using the same descriptors as the Nature Live participants, indicating that as whole both samples had a similar range of perceptions. Each student mentioned expectations or perceptions within a mean of four descriptor categories. Students did exhibit similar types of behaviours in terms of changes to their perceptions of scientists; three of the four most frequently populated behaviour groups for students and visitors were the same: ‘change; confirm’, ‘all change’ and ‘emerge’. It is reasonable, therefore, to argue that visitors and students demonstrated similar types of behaviours in terms of the changes to their perceptions of scientists following events.

5.5 Trends in changes in perceptions of scientists

The above section described how participants exhibited changes in their perceptions of scientists, following events; the types of behaviours exhibited could be grouped in ten ways. In this section, I explore where the changes might have happened. It is extremely complicated to categorise individuals on the precise nature of the changes to their perceptions of scientists, as everyone has unique ‘starting points’ from which multiple combinations of behaviours can lead to a huge variety of ‘end points’ in terms of sets of ideas about scientists.

To examine where trends in changes in perceptions might be taking place, I have adopted a different approach. The descriptors used by participants after the session to describe the scientist were compared to their expectations in order to investigate the impact on participants’ identification of scientists. The presence of descriptors used by individuals under each descriptor category were recorded for each interview (pre-session, post-session, delayed post-session). Considering these frequencies together, a picture of how many individuals were using descriptors under each descriptor category, over the three time points, can be gained. These data are presented in Figures 16 and 17, for Nature Live visitors and A-level students respectively.

Proportions of descriptors used per time period have been calculated and presented, in order to control for potential differences due to the different lengths of the pre-session, post-session and delayed post-session interviews. For example, in the longer delayed post-session interviews there was a higher available ‘opportunity to comment’ – participants had more chance to say more about the scientists. However, in using proportions per time period the effect of this opportunity to comment is controlled for, and comparisons can be made more confidently across time periods.

Figure 16. Proportion of Nature Live visitors using descriptors over time.

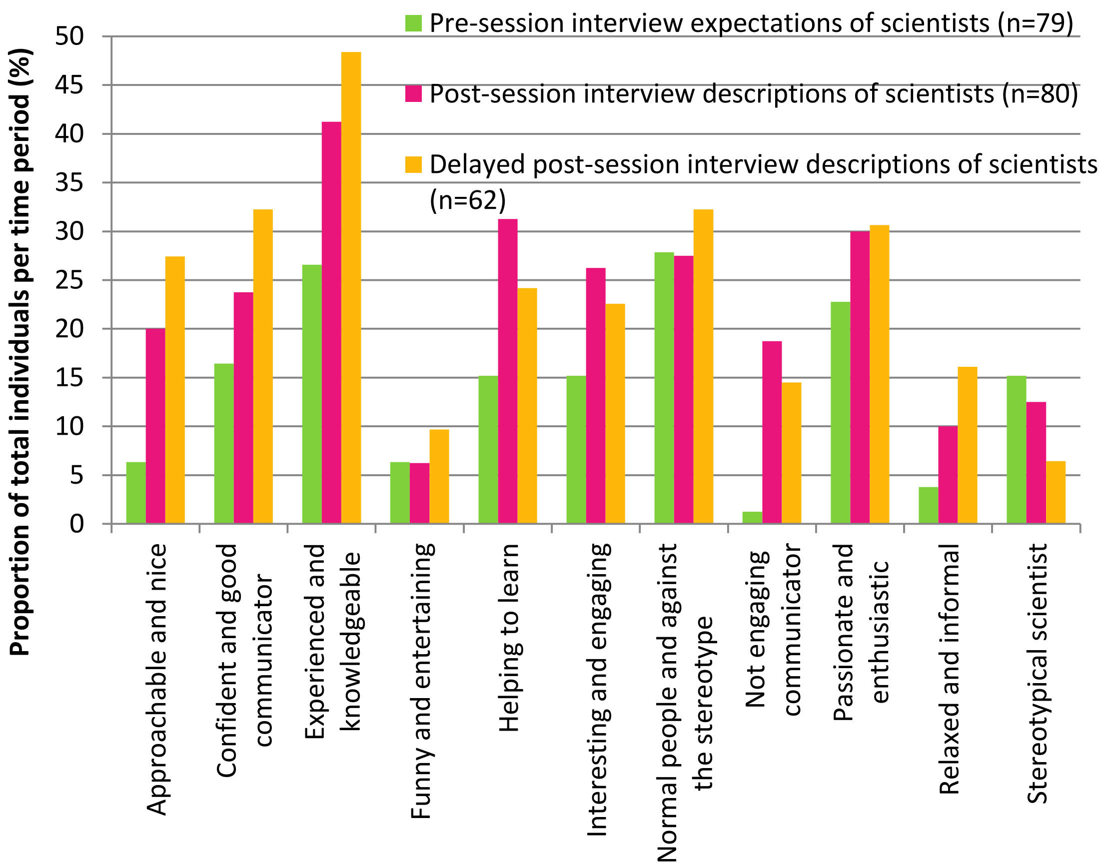
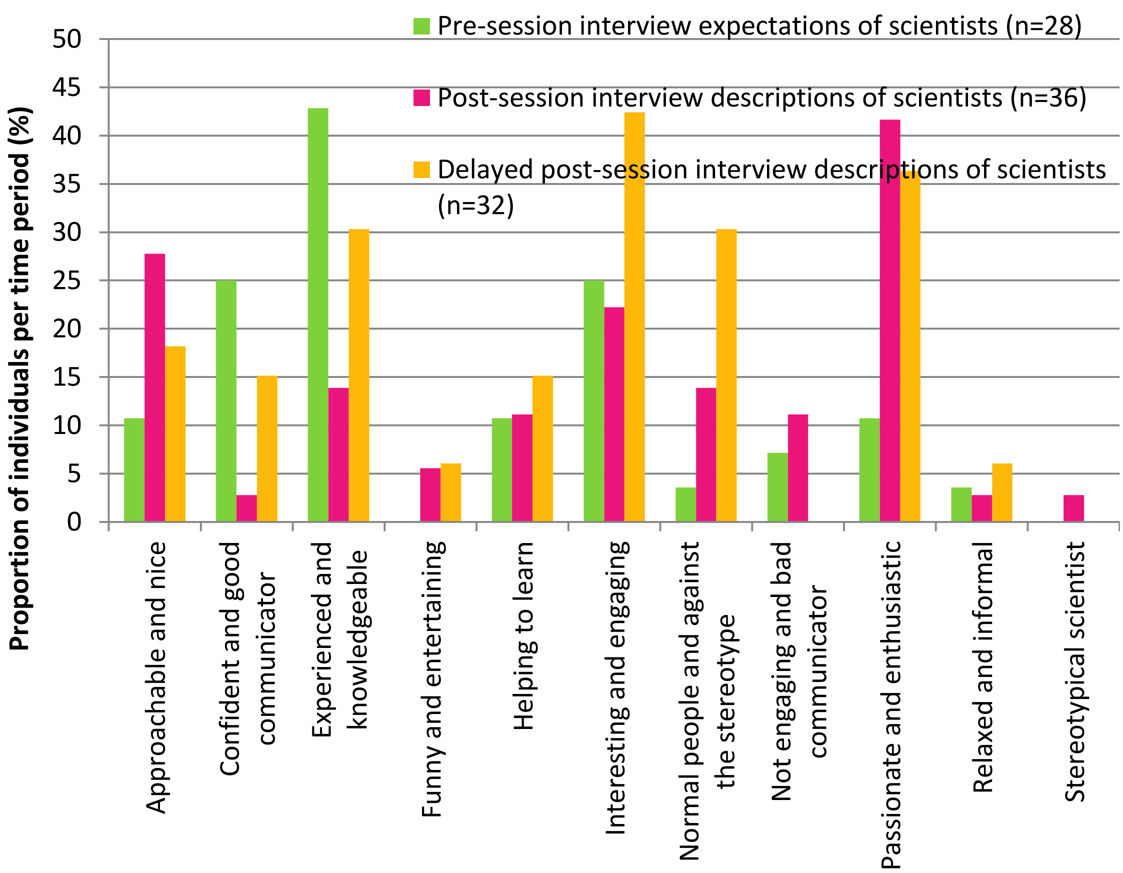


Figure 17. Proportion of A-level students using descriptors over time.



Figures 16 and 17 give a sense of the general trend seen in terms of changes in descriptors used. It is acknowledged that this way of presenting the data does not illustrate the perceptions held by *individuals* over time, but it explores the data at a *population* level and complements the other sections of this chapter which focus on individuals as the unit of analysis and which describe key individuals.

Figures 16 and 17 show key trends in changes in perceptions following meeting scientists. After meeting scientists, visitors and students are more likely to describe them as approachable and nice, normal and not like the stereotypical image, interesting, engaging, passionate and enthusiastic.

There are some differences between the samples of participants in terms of their trends in perceptions of scientists. Nature Live visitors are more likely to describe scientists as engaging and confident communicators, and experienced and knowledgeable experts following the event compared to before, a trend which is not mirrored in the A-level student data. Interestingly visitors also become more critical of the scientist after the event in terms of their communication skills, not seen to the same extent in the student data.

Differences between visitors and students may be due to the slightly different experiences they have. For example, A-level students meet two different scientists for example, one in their laboratory, collections or work spaces, whereas Nature Live visitors usually only meet one. A-level students also arrive with a different frame of mind – students are expecting to learn about the work and life of a scientist when they arrive at the Museum, Nature Live visitors are likely to arrive with a variety of other agendas. Despite the differences between the two, these data show that meeting a scientist does have an effect on perceptions of scientists across different audiences.

So far this chapter has discussed where changes and trends in participants' identification of scientists have occurred, both in terms of behaviours relating to perceptions and trends in the types of perceptions held by participants. In the remainder of the chapter the content of participants' perceptions is explored, revealing contrasts amongst individuals' ideas about scientists.

5.6 Duality and contrasts in perceptions of scientists

As mentioned above, the categories of descriptors were identified from the interview transcripts and similar descriptors (adjectives or phrases) were clustered together into the eleven descriptor categories. In looking at the categories more closely there are some which are contrasting or opposing. A duality is evident in visitors' and students' perceptions of scientists: on one hand perceptions related to the scientist being an 'everyday person', someone who is friendly, down-to-earth and who might take the time to explain things well to those who are not within their research area. On the other hand perceptions related to the scientist being an expert, knowledgeable and experienced in their field and someone who was important and unusual to meet, often aligning with traditional stereotypical characteristics of scientists lacking social skills. Table 10 indicates which descriptor categories make up both sides of the duality.

Table 10. Descriptor categories forming two contrasting perceptions of scientists.

Scientists as experienced, knowledgeable and unsociable experts	Scientists as approachable, friendly and normal 'everyday' people
• Experienced and knowledgeable expert • Stereotypical scientist characteristics • Not engaging and bad communicator	• Approachable and nice • Confident and good communicator • Funny and entertaining • Helping to learn • Interesting and engaging • Normal people and against the stereotype • Passionate and enthusiastic • Relaxed and informal

Perceptions of scientists which both covered 'everyday' and 'expert' sides of the duality described above were held simultaneously by 53 out of the 81 visitors, and 23 of the 38 A-level students. That is to say, in the same interview, individuals mentioned ideas which showed that they perceived scientists as both experts and as 'everyday people'.

By examining in which interviews dual perceptions were revealed, it can be determined whether this duality in ideas about scientists was triggered, confirmed or challenged by the experience of meeting scientists. For 23 participants, contrasting ideas were mentioned in pre-session interviews and were then also mentioned in post-session or delayed post-session interview, showing that the experience of meeting a scientist had supported the existence of a duality in perceptions of scientists. For 39 participants a duality in ideas about scientists as both ‘everyday’ and experts was triggered by meeting scientists: contrasting ideas were not present in pre-session interviews but emerged in later interviews. For a further five students a duality was present in post-session or delayed post-session interviews, but no pre-session interview data was gained to determine if multiplicity of perceptions had been triggered or confirmed by the experience. For nine participants dual perceptions of scientists were not confirmed by their experience; they had contrasting ideas about scientists before the session but did not reveal dual ideas in later interviews. The majority (seven) of these individuals only mentioned descriptors in the ‘everyday’ categories following meeting scientists, suggesting that they no longer held perceptions in the other side of the duality about scientists being experts and having stereotypical characteristics.

Cases of duality in perceptions from five of the key case individuals from above (section 5.4) are presented in Table 11 to illustrate how visitors and students held these contrasting ideas simultaneously around perceptions of scientists.

Table 11. Examples of visitors' and students' dual perceptions of scientists.

Participant **(Interview)** **Behaviour relating to contrasting perceptions over time**	**Perceptions of scientist as stereotypical expert**	**Perceptions of scientist as 'everyday' and approachable**
Anne (NL-D) **(Post-session interview)** **Duality in perceptions emerged following meeting scientists**	*A wonderful achievement that he actually got it* [data he had been studying] (Experienced and knowledgeable expert)	*Just a normal chappy* (Normal person and against the stereotype)
Serafina (NL-V) **(Pre-session interview)** **Duality in perceptions was evident in pre-session expectations and delayed post-session interviews**	*Ross from Friends!...Geeky, but not too geeky* (Stereotypical scientist characteristics)	*I think they are just normal people, just more interested in one thing than another* (Normal people and against the stereotype)
Kate (NL-L) **(Post-session interview)** **Duality in perceptions arose in pre-session expectations and delayed post-session interviews**	*His level is obviously a lot higher than mine* (Experienced and knowledgeable expert)	*Used a demonstration with a stick to explain what was going on…he gave us a lot of information* (Helping to learn)
Pat (NL-P) **(Delayed post-session interview)** **Duality in perceptions confirmed following meeting scientists**	*Knowledgeable and knows more about certain things* (Experienced and knowledgeable expert)	*Open and friendly, yeah you weren't made to feel like inferior or anything* (Approachable and nice)
Betty Boop (AL-C) **(Delayed post-session interview)** **Duality in perceptions emerged as a result of meeting scientists**	*And she was saying interesting facts that I don't think many people know* (Experienced and knowledgeable expert)	*And, like, we understood everything she was saying.* (Helping to learn)

The data were analysed to explore whether there were any trends in whether participants had multiple contrasting perceptions about scientists. For example, one might expect those with scientific backgrounds themselves could have different perceptions of scientists compared to those without, or perhaps that A-level students might have different perceptions compared to the adult visitors. No such patterns were identified in this study. It should be noted, however, that there were relatively few visitors with a scientific background compared to those without (25 of the 81 visitors had studied science at university; 11 said they were currently working in science) and, therefore, any patterns relating to this may not have been identifiable in the current sample.

I have identified a dual identity in participants' identification of scientists around the themes of expertise and 'normality' or accessibility. Visitors and students valued the expertise and experience of the scientists, and thought of them as similar to the stereotypical image of scientists. At the same time, visitors and students described scientists as approachable and friendly, appreciated that the scientist helped them to learn and found them down to earth. The themes of expertise and the 'special' nature of scientists, alongside scientists being accessible and 'everyday', are explored further below, where data from interviews and field-notes adds to the data presented here from descriptors.

5.7 Expertise and the 'special' nature of scientists

The theme of expertise emerged in visitors' and students' descriptions of scientists, with interview responses including comments about the scientist being intelligent, knowledgeable and a well-known individual in their field of research. The descriptor group 'experienced and knowledgeable expert' was the most frequently mentioned in terms of numbers of visitors, in the post-session and delayed post-session interviews. The layout of the studio, data from field-notes, and interview responses about the session also indicates how the session presented the scientists as experts

5.7.1 Studio layout reinforcing the expert nature of scientists

The arrangement of the space where visitors and students met scientists added to the portrayal of scientists as experts and 'special'. The Attenborough Studio is the location for the Nature Live events for adult visitors and A-level students. The way the Studio is laid out suggests the status of the presenters, Figure 18. This context is important to consider when analysing the comments made by visitors about the expertise of the scientist.

Figure 18. Attenborough Studio set-up.

The scientist usually sat at the front of the Studio next to the Nature Live host. In Figure 18, the scientist is the male and the female host is on the right. There is then a large space before the audience seating begins. This distance separates the audience from the scientist, perhaps creating a barrier or distinction between the two. The audience seating was tiered, so that everyone had a clear view of the front of the Studio and all seats point towards the scientist. The scientist and the host have microphones; audience members must indicate their interest in speaking – usually by raising a hand – before the host hands them a microphone. The scientist did not once hand over their microphone to the audience in the sessions observed. This distribution of microphones indicates power dynamics in terms of who has something to say about the subject and whose contribution is most valued. The screens of the Studio face the audience; the scientist has their back to the screens, although they can see what is projected on a small tablet in front of them. This set-up indicates that the scientist does not need to see what is on the screens – they already know this – whereas the audience require the visual presentations. Despite the Studio layout being conducive to the engagement and involvement of the audience, it also distinguishes the scientist as an expert in the situation (for another analysis of power balance and negotiation in dialogue events in museums see Davies, 2013).

The location and set-up of A-level behind-the-scenes tours demonstrates similar themes. Students are guided around the research spaces and the laboratories used by the scientists – another context in which the scientist is portrayed as being an expert. The scientist determines where the group stops for discussion, their belongings are in the space and the scientist has to let the students into the space through secured doors; all subtle indications that the scientist is the expert in relation to the audience.

5.7.2 Evidence from field-notes indicating the representation of scientists as experts in Nature Live and A-level sessions

Data from the field-notes taken in Nature Live events and A-level sessions highlight how scientists were presented as experts in individual sessions. There were 90 occurrences present in 51 of the 61 events (Nature Live and A-level sessions) studied in which scientists were presented as an expert, or had acted in some way to highlight their own expertise in the field.

For example, the first comment by the Host about the scientist in a Nature Live session usually related to the scientist's expertise or specialism. Hosts would begin by saying 'We are very lucky to have here today…', indicating that meeting a scientist is something that is a 'special' and valuable experience. The specialism of the scientist would also be mentioned and hosts would often ask about the role of the scientist in the Museum.

The majority of the mentions of expertise were not qualified – there was no specific validation to the claim that scientists were indeed experts in their particular field. Details such as the length of time working at the Museum, or particular interests or projects were often stated, however these do not provide the audience with evidence on which to judge the quality or level of the scientists' research. For example, the following field-notes illustrate how scientists are presented or present themselves as experts without additional qualification:

> *Regina introduces Molly, saying that she takes care of many specimens as she is collections manager and asks Molly to tell us more about her collections. Molly explains she manages the aquatic invertebrate collection and a team of people who each have individual specialisms – her particular interest is in Crustacea.* (NL-I field-notes)

> *Bill says that he's enjoyed working on frogs for a long time and has now been working in the Museum for over 36 years.* (NL-J field-notes)

In most of the sessions observed, the scientist spoke about their particular subject or project for the majority of the time. Expertise is implied, therefore, in that the scientist is predominantly the individual speaking and providing information, whereas the host and the audience members ask questions.

There are some instances where validation was provided for expertise. Three forms of validation emerged from the data: education, consultancy and publishing. Comments about the education of the scientist were noted in seven events, providing further evidence for the scientist's expertise. For example:

> *Emily asks Amy what she does at the Museum and Amy explains that she is an early career researcher; she just finished her PhD and is now doing postdoctoral research.* (NL-Zq field-notes)

There were mentions in six events of scientists being asked to be involved in projects as an expert, often for external organisations such as the police. Information about the consultant roles scientists played provided the audience with evidence of expertise, as identified and respected by others:

> *Craig described why the Museum was called in by the Rwandan government to develop the memorial, and the specialisation and expertise in the Museum in dealing with and conserving human remains.* (NL-A field-notes)

Finally, there were mentions in four events of scientists authoring published work including papers in peer-reviewed journals. The fact that scientists had published work may have assured the audience that their work is respected and trusted by other experts in their field and that it is contributing to new knowledge. For example:

> *She [Isabelle] then asks about the paper Douglas has written about this [topic] – he says that they are just carrying out some minor corrections on the paper and hopefully it will be published in the next few months.* (NL-Zn field-notes)

5.7.3 Interview responses illustrating visitors' and students' perceptions of scientists as experts

Interview responses also gave an insight into how visitors and students were seeing scientists as experts or possessing high status. As visitors and students were speaking about their experiences of meeting scientists, they identified the characteristics of the sessions that they valued the most. Two of these characteristics related to the idea of scientists being experts and knowledgeable, and can perhaps be conceptualised as authenticity and exclusivity.

Meeting a scientist was a new and authentic experience for the students and visitors taking part. From the responses of the students, it is clear that the authentic nature of meeting the scientist had an impact on them. The authentic or 'real' nature of the experience was mentioned by 15 students. Students frequently used the words 'real' and 'actual', spoke about seeing the 'actual' people doing the science, the 'real' specimens and equipment, in the places where it 'really' happens. Students enjoyed hearing about scientists' own personal experiences of having actually done the work themselves:

Imi	*The second one was just really cool to find out about her experiences and her pictures were really, really cool, so like picking up different fossils and things like that, it was really nice, like to see again her own experience.* (AL-D group, delayed post-session interview)

In particular, students mentioned sharing the experiences of the scientists who have actually carried out the work, and also the real enthusiasm of those individuals. Students mentioned seeing an 'actual scientist', presumably in contrast to other images of scientists or sources of science information.

For some students, meeting scientists represented access to real science and real specimens. In the extract below, two students suggest that it is not only seeing someone who is an active researcher which is an important experience for them, but it is also the case that they would like to see someone actually doing the science in front of them, carrying out experiments or other aspects of their job. This quote indicates that students are hoping for this sort of experience before meeting scientists, it is not only an impact they appreciate afterwards:

Hannah	*Yeah, because you know how we do experiments in class, I think it would be cool to see like proper scientists, you know do like real experiments.*

Experiments you know that are actually like going towards something, or mean something. (AL-A group, pre-session interview)

Students compared the experience of meeting real scientists to other places where they had learned about science, for example from their teachers, the television and the main galleries of the Museum. They point out the ‘real’ nature of meeting the scientist, compared to the ‘non-real’ experiences such as television programmes, teachers and other experiences outside of school:

Einstein *I never really considered forensic stuff, apart from CSI – which I know is, like, completely over-dramatised. So I really enjoyed watching actually how it’s done, not just on the telly.* (AL-B group, post-session interview)

Imi *It was also quite nice because she was sharing her own experience with us. And she was, like, talking and you could see that it kind of affected her and stuff like that. It was her experience, it’s not like ‘Oh yeah I did this’, but actually she’s just read it from a script. You could see it was all personal to her. That was quite cool.*

Interviewer *Do you think that makes a difference, having that…?*

Imi *Yeah it does, yeah. Because, well it’s the same as having a teacher standing up, and ‘Oh yeah, it’s the same in everyday life, you can’t do this job without doing this’. But it’s different if they turn around and say yeah so, ‘I did this one day and it was then that I needed this particular thing’. Or if you can, if they actually share their experience with you, you could then put it into use maybe one day if you’re going into what they are speaking about you can have that experience as your own as well. So rather than just being general, it’s quite personal.* (AL-D group, delayed post-session interview)

Many visitors (n = 28) also compared the experience of meeting a scientist with other formats and ways of learning, for example, watching television programmes or reading labels from exhibitions at the Museum. There were a number of benefits visitors identified that they gained from the Nature Live event which they felt they would not get with other learning experiences. Visitors felt that they were able to learn more, it was more interesting, more captivating and they valued the chance to ask the scientists questions, all unique features they felt were relevant to meeting scientists compared with other learning experiences due to the authentic nature of the interaction with the scientist.

The importance of authenticity has been discussed in relation to museum learning experiences – often museums have access to specimens, collections and experts which visitors would not come across in their everyday life (Braund & Reiss, 2006; Leinhardt & Crowley, 2001). In this way experts are authentic and novel or special, which mirrors the findings of the current study in which visitors felt that meeting real scientists was not something they would do every day and was special.

Further to the theme of authenticity – seeing the actual scientists and their work – students mentioned the exclusivity of the experience. The session was perceived to be a rare opportunity for the students and they felt that they had seen things which other visitors to the Museum may not otherwise be able to see. Exclusivity is defined here in terms of the experience being perceived to be something 'special' and unique. For the majority of students, going 'behind-the-scenes' in particular was something which was memorable:

Shaniqua *If someone asked me about it I'd probably tell them it was one of the best trips we've been on, because it was the most interesting, erm, and the fact that we managed to go behind-the-scenes and see all the exhibits – the stuff, the animal specimens that were stored, was cool.* (AL-F group, delayed post-session interview)

Eddie *I also think it was good to see, like, behind-the-scenes of the Museum, which people don't normally get to see, so that was cool.* (AL-H group, delayed post-session interview)

In the quote below, Betty Boop, key case individual from above, picks up on the exclusivity of the information the scientists are giving them, they are able to access information that others might not, through talking to the scientist:

Betty Boop *Well the first one, she was talking about chocolate. And she was saying interesting facts that I don't think many people know. Like how much percentage is actually chocolate in the chocolate we buy…* (AL-C group, delayed post-session interview)

Finally, some students mentioned specifically that the unique event has been organised especially for them. This exclusivity is something the students seemed to appreciate and remember afterwards:

Louis Pasteur	*My favourite bit was going into the, like, secret room, which only 12 people were allowed to go in, and he had to get permission for us to go there and we saw like really old books from the famous botanists. That was definitely the best bit for me.* (AL-B group, post-session interview)

Visitors to Nature Live events also commented that meeting a scientist was a 'special' experience for them due to the authenticity of the scientist and that it had been different to other museum experiences in that way. Visitors' comments about authenticity and exclusivity were frequently combined – visitors valued the experience of meeting a real scientist because it was not something they did every day and it was 'special'. Twenty-seven visitors described the experience of meeting a scientist as authentic or special. Visitors mentioned that they valued meeting a scientist in terms of receiving accurate and reliable information and having access to the passion of someone who actually researches the subject for their job. The following comments, including one from key case individual Pat, illustrate how visitors considered meeting a real scientist a unique experience:

Elvis	*I think it's, the actual thing and it's the real scientists, it's not like Brian Cox, these are the real, they can inspire*. (NL-Za, post-session interview)
Pat	*So she was very good, added a bit of life, a bit of reality to it – rather than just staring at ammonites on the wall, she was actually there, adds a new dimension. It's good to hear from someone who is actually doing the work.* (NL-Zz, post-session interview)
Rick	*Well that was probably from my point of view, the certainly the most interesting part. Because it was an opportunity to sit down and listen to someone, a professional, talk passionately about something they obviously knew quite a lot about.* (NL-Zk, delayed post-session interview)

The majority of comments in this group about the authenticity and exclusivity of the scientist were positive. However, one visitor felt frustrated because he was expecting more of the scientist's own expertise to be covered in the session, relating to the fact that he did not have the opportunity to hear scientists speak every day, so wanted to make the most of the opportunity:

Moriarty *Well yeah – obviously he's an expert, so I would like an expert, you know show me your expertise, show me there's something out there, any, obviously you could train anyone to give that lecture. Maybe just the wrong questions were asked?* (NL-Q, post-session interview)

The frustration of Moriarty represents a tension for public engagement in that scientists are expected to be experts and, therefore, visitors want them to talk about their work rather than have a more open dialogue where visitors contribute to the discussion. This presents a problem, however, in terms of identifying *with* scientists due to the differences in perceived status between the visitor and scientist. These themes are returned to in Chapter 6 in terms of identifying *with* scientists.

These themes of authenticity and exclusivity in the experiences of the participants in the current study align with other research suggesting that such experiences may encourage science learning and motivation (for example Braund & Reiss, 2006). Interaction with scientists, in particular, is one suggestion put forward to increase access to authentic science for students and, therefore, promote the development of science identities (Lee & Butler, 2003). The current study supports the recommendations of Lee and Butler (2003) in that it demonstrates some of the positive impacts of meeting scientists on the development of identification of and with scientists.

Through this theme of exclusivity, a question emerges about the perceived status of the scientist and how 'special' they are believed to be, from the perspective of the participants. In valuing the unique experience of meeting a scientist, visitors and students are inferring that they hold scientists to have a high status compared to other individuals; the host of the session, for example, does not seem to be held with such regard as the scientist. This perception of scientists as individuals of high status raises issues which will be followed in the discussion chapter (Chapter 8), around the power relations in Nature Live and the balance of status of scientists and audience in the sessions. I would argue that visitors and scientists do not have equal footing in Nature Live, as might be aimed for in a 'true' dialogic public engagement model. A similar situation is seen in Davies' study into dialogue events in the Dana Centre, London (2013).

In summary, meeting scientists at the Museum was seen by participants as an authentic and exclusive experience. Any criticisms made about the session itself were in relation to one of these characteristics not being fulfilled, such as the one above about the expertise of the scientist. This finding reinforces how important these two characteristics were to the success of the sessions from the visitors' perspective, and therefore, poses practical implications which will be important to bear in mind in the future development of sessions where visitors can meet scientists. The fact that visitors and students saw the sessions as authentic and exclusive supports the perception of scientists as experts; scientists had real experience and knowledge and to interact with them was a rare and 'special' opportunity.

Visitors seeing scientists less as 'normal' people and more as knowledgeable and experienced experts may pose a dilemma for public engagement practice. Is an image of an extraordinary expert, who is not seen as 'everyday' or 'one of the people', really a beneficial representation of scientists to portray? Scientists might be seen as having all the answers and the 'keepers of knowledge'. For visitors who do not have a scientific background, the idea of an expert might seem inaccessible and out of reach. If that is the image visitors are developing from Nature Live events, it may actually be detrimental to promoting future engagement. Visitors may be put off by seeing scientists as all-knowledgeable experts.

Issues of expertise, particularly the relative expertise of scientists and publics, have been discussed with a recognition that public engagement should incorporate many forms of expertise to create a more equal forum for dialogue on scientific issues (Irwin & Wynne, 1996; Wynne, 1992). From this perspective, one could argue that an image of scientists as 'everyday' people who are good at their jobs, just like other individuals who are successful in their respective careers, would be more conducive to future science engagement and developing confidence with science learning.

Other interview responses and field-note data gave a different perspective on perceptions of scientists to that discussed above – visitors also saw them as accessible and 'everyday' – forming an interesting dual identity in participants' conceptual ecologies around perceptions of scientists.

5.8 Accessible and 'everyday' nature of scientists

In contrast to the findings in the previous section, some visitors and students also saw scientists as more approachable and friendly after meeting them. Students were also more likely to describe scientists as 'normal' people after the sessions. This finding suggests that although participants perceived scientists as experts and felt that the opportunity to meet a scientist was a rare and exclusive event, they simultaneously began to see them as equals, 'everyday' people with whom they were comfortable to interact.

5.8.1 Evidence from field-notes indicating the representation of scientists as 'everyday' in Nature Live and A-level sessions

There were a number of ways in which the scientists were portrayed as accessible or 'normal' and 'everyday' within sessions. In total, the normality or down to earth nature of the scientist was referred to 110 times in 45 events (Nature Live and A-level sessions), sometimes in a general way and sometimes with further example or illustration. For instance, in 21 events details were shared about the scientists' life outside of work including their past career paths, about their family, where they grew up, or interests outside of work. For example:

> *It is when talking about heat and thermal imaging cameras and technology, that Martin shows pictures of his wife drinking a cup of tea, and his dog*. (Al-A field-notes)

Humour was used in 21 events, presenting the scientist as more accessible and friendly. Humour was used both by the scientist themselves telling jokes and also by the hosts in reference to the scientist:

> *Maurice* [host] *jokes that Susie* [scientist] *plays on the cricket team with him and some of the dinosaur movement looks similar to her post-match celebration*. (Al-D field-notes)

There were eight events where scientists were presented as vulnerable, to a degree, or where areas of weakness in the scientist's expertise or skills were revealed.

> *When Michael is trying to show the pictures of these bees he gets muddled up with the technology – trying to find one picture, and tells the audience that it is his first session and that he wasn't used to all this fancy technology*. (NL-B field-notes)

The field-notes, therefore, indicate how scientists may have been portrayed as accessible, friendly and approachable to visitors and students, as 'everyday' people. Evidence from interview responses also suggests that visitors and students found the experience of meeting scientists to be interactive and accessible.

5.8.2 Interview data illustrating visitors' and students' perceptions of scientists as 'everyday' people

In addition to comments about the authenticity and exclusivity of the Nature Live sessions, students and visitors particularly commented on the interactive nature of the experience as something that they valued. Whilst the experience was special, it was also interactive and, therefore, accessible. Students and visitors could pose their questions to the scientists, share experiences with the scientists and touch the real specimens and equipment. For example, these students spoke positively about the interactive nature of the sessions they attended with the scientists:

Einstein *It was a lot more hands-on today, like being able to see the specimens actually there. Because normally when you have lectures it's like PowerPoints and pictures and things, today you go to see it first-hand, which was good.* (AL-B, post-session interview)

Eddie *I didn't think it would be as interactive as it was, to be honest, I thought this would be more museum-like.* (AL-H group, post-session interview)

The interactivity is not something which was necessarily a surprise to some of the students; they had been expecting and hoping that the session would have some elements of interactivity. These are two examples of student responses to one interview question 'What are you expecting to do at the Museum on Monday?':

Roger Moore *Well, of course, learn about science and see a bunch of diagrams and explaining things a lot better than a textbook would. More hands-on stuff.* (AL-G group, pre-session interview)

Ahmed *Probably I don't think they will be sitting there with a paper reading out the same notes over and over again, it will be quite interactive surroundings, models and stuff like that.* (AL-I group, pre-session interview)

These comments about interactivity relate to those made about authenticity in the previous section. Participants stated that they valued the authentic experience of meeting a scientist, comparing it to seeing scientists on the television. The format of the Nature Live events add interactivity to the experience of 'meeting scientists' compared to seeing scientists on the television, suggesting, perhaps, why the experience was so impactful.

In contrast to the quotes above, students who didn't enjoy the sessions so much indicated that they would have liked it to be more interactive:

Sahara *If it was more, I dunno, active for the audience. Like to put our hands up, not just voting through buttons. I didn't like that.* (AL-C group, delayed post-session interview)

This point highlights the importance of interactivity in making the exclusive and unique experience of meeting a real scientist accessible to students and visitors.

Visitors to Nature Live also commented on the interactivity of the sessions in their expectations and descriptions following the event. A total of 28 visitors mentioned the sessions being interactive in post-session and delayed post-session interviews. Visitors enjoyed the opportunities to become involved in the session, to ask questions, or to comment when asked by the scientists or hosts. Visitors remarked on the use of diverse formats and media, such as visual aids, videos, specimens and even tasting samples.

Visitors also felt that the fact that information was accessible and pitched at the right level for the audience was an important characteristic of the session. Thirty-two visitors mentioned the level at which the session was pitched in terms of the information given, in the post-session and delayed post-session interviews. Encouragingly, 22 people thought the session was accessible in terms of the level and complexity of information given and the way it was delivered. Six others would have liked more detailed or complex information and four visitors felt that the session was too complex and assumed too much knowledge on the part of the audience.

An interactive presentation is likely to encourage audience participation, increasing their level of engagement and, therefore, their influence on the level of information discussed and the direction of the session (Davies *et al.*, 2009). The fact that visitors enjoyed the interactive aspect of the session may be because it is something they had not expected to encounter in the Museum, especially around science content. DeWitt's (2013) study highlights that family visitors to the Natural History Museum often saw a tension between the term science and terms such as child-friendly, hands-on and interesting; adults in family groups were reluctant to label something as 'science-y', due to the fact that it had also been fun and interactive. It may be that visitors in the current study were experiencing a similar tension in their ideas in that visitors valued the interactivity of the session because it was something they had not been expecting of something 'science-y'. Experiences in Nature Live may, therefore, have an impact on visitors' perceptions of science and what counts as something 'science-y'.

The importance of interactivity and accessibility in learning environments is mirrored in a study into student interest on a visit to a zoo (Dohn, 2013). This study identified the situational variables that could trigger short-term interest during a zoo visit as: hands-on activities, social involvement, surprise, novelty and knowledge acquisition. The first four variables listed map onto the themes of exclusivity and interactivity identified in the current study regarding meeting scientists at a museum. These findings, therefore, provide guidance for the development of other learning experiences. The findings may also provide an indication of why the experience of meeting scientists is impactful in terms of altering perceptions, discussed further in Chapters 6 and 7.

5.8.3 Summary of contrasting ideas: Accessibility and interactivity with expertise and exclusivity

In section 5.6 it was demonstrated that visitors held simultaneous ideas about scientists which seemed to contrast, for example that they were both an expert in their field and also a relaxed and down to earth person. In section 5.7 and 5.8, data from field-notes is explored alongside comments visitors and students made about the session itself. Again, a duality is evident. On the one hand, visitors described the session as accessible and interactive. The session was pitched at an engaging and suitable level of information for them and the rest of the audience and it felt relaxed and intimate enough that they feel comfortable taking part and asking questions. On the other hand, visitors described the sessions as authentic and exclusive. The sessions were not something they would have the opportunity to see every day, and real specimens and real scientists made the sessions special and authentic especially compared to other experiences they might encounter such as television programmes and school lessons. Twenty-two visitors simultaneously mentioned aspects of the session that demonstrated this contrast in ideas: comments about the session being accessible and the right level of information and/or interactive, at the same time as being authentic and special and/or unique compared to other experiences.

Visitors and students, therefore, seemed to hold simultaneous ideas of scientists as being experts and yet accessible, supported by factors in events that presented scientists as both specialists in their field and as 'everyday' people. Visitors to dialogue events held at the Dana Centre in London indicated similar multiple ideas to participants in the current study (Davies *et al.*, 2009). Visitors valued the interactive and informal nature of the session and the ability to ask questions to the scientists. At the same time, Dana Centre visitors also reported that they needed to be provided with some new information or content from the expert to begin the event; visitors felt that without fresh information from the specialist they could not develop their ideas on the subject and take part in interactions about it. It can be concluded, therefore, that scientists play two roles in public engagement activities: the expert and the 'person like me'. Both might be necessary roles for the success of the engagement activity.

5.9 Summary

This chapter has explored students' and visitors' identification *of* scientists and the impacts of meeting scientists on their perceptions. The data presented confirms the existence of a conceptual ecology around ideas about scientists, in that individual visitors and students hold multiple ideas about scientists which may be related, linked and vary in prominence (diSessa, 2002; Reeve & Bell, 2009). Ten ways were identified in which these networks of multiple perceptions and ideas might change as a result of meeting scientists; visitors and students were grouped according to the types of behaviours they exhibited in relation to their perceptions of scientists over time.

Additionally, contrasting themes within the network of perceptions about scientists were identified and discussed. Visitors and students hold these multiple contrasting ideas simultaneously, and often the experience of meeting scientists triggered multiple contrasting ideas. Two broad notions of scientists, one as the expert – all-knowing, high status, special and authentic, the other of the 'everyday' person – 'normal', friendly, down to earth and approachable, were evident. Further examination of comments in interviews and field-notes illustrated these themes in more detail.

Perceptions of scientists are fundamental to the development of scientific literacy and further engagement with science; individuals need to see science as something that people ‘like them’ enjoy and find important, or identify role models in science which they might aspire to (Brickhouse *et al.*, 2000; Holland *et al.*, 1998), rather than accept the idea that science is carried out by ‘others’ or is ‘important but not for me’ (Archer *et al.*, 2010; Bennett & Hogarth, 2009; Jenkins & Nelson, 2005). Building on this analysis of participants’ perceptions of scientists, in the next chapter, data is discussed relating to how visitors and students identify *with* the scientists they meet, making personal connections and links and positioning themselves as closer to the scientist as a result of meeting them.

Chapter 6: Identification *with* scientists

6.1 Introduction

The conclusion of the previous chapter was that meeting scientists had multiple and complex impacts on visitors' and students' perceptions of scientists and science. As yet, however, the nature of the impacts of meeting a scientist on visitors has not been fully explored. In this chapter I focus on another type of impact: participants' identification *with* scientists and science. The findings reported here provide evidence of students and visitors making personal links and associations to the scientists they met and the science they heard about, developing interest and empathy towards the scientist themselves. Consideration of the findings allows conclusions to be made about whether impacts operated at a personal level, that is, whether any development of science identities occurred as a result of meeting scientists. In this way, the discussion moves from passive impacts on scientific literacy, such as increased knowledge of scientific concepts and an appreciation that science is important, to those impacts with the potential to effect engagement behaviours and interest for example feeling that science is 'for me'. Chapter 7 then builds on this chapter by exploring to what extent impacts on engagement, behaviours and interests as well as on attitudes and perceptions last beyond the immediate experience.

This research contributes to an understanding of how meeting scientists may lead visitors and students to identify more closely with science and scientists. In this chapter, I explore if and how meeting scientists has an impact on whether participants identify connections with the scientists or feel closer to the research of the scientist, and whether participants develop any interest in the scientist themselves. Identifying more closely with scientists indicates seeing science as relevant and personally interesting and supports the development of science identities (Kozoll & Osborne, 2004; Tan & Barton, 2008). More developed science identities may lead to increased scientific literacy due to awareness and understanding of science and the nature of science. They may also lead to more science engagement due to increased interest in science, perceiving science as relevant and being more confident to engage in science. Identity theory is used in this chapter to discuss identification with others and how the development of identities influences interests and engagement in related activities (Holland *et al.*, 1998).

Questions generated by the visitors and students were analysed by topic to explore trends in interests at a whole sample level, with illustrations from the key case individuals presented in Chapter 5. Participants identified more closely with the scientists following the meet-the-scientist sessions, making personal links to the scientists and the scientific topic. The experience also sparked new interests relevant to the session. Findings suggest that interactions with scientists contribute to increasing scientific literacy and engagement with science in students and adult visitors.

6.2 Making connections: identifying with scientists

Comments from post-session and delayed post-session interviews were analysed to explore how participants identified with scientists as a result of meeting them; evidence of visitors and students making links to the scientists were explored. Links were made between the participants and the scientists in two ways. Firstly, visitors identified similarities and common themes between their own personal ideas and experiences and those of the scientist. The experience of meeting the scientist was integrated into visitors' prior interests and ideas. Secondly, visitors formed new links to the subject, finding unexpected elements interesting or connecting to the topic in new ways. These two themes relating to making connections are discussed below.

Seeing connections with, and relevance of, science and scientists contributes to increasing scientific literacy and engagement by linking science to the life of the visitor, increasing the relevance of science to the visitor and facilitating new opportunities for engagement with science in the future (Kozoll & Osborne, 2004). The ability to see the personal relevance in a subject may predict future engagement; teachers supporting students to see the relevance of the subject to their personal lives are more likely to foster autonomous engagement with the subject in students than teachers using other strategies, such as demonstrating the historical or societal significance of a particular aspect of science (Assor *et al*., 2002). Students identified with scientists differently and were more focused on science careers than were Nature Live visitors, a point which is discussed in section 6.4.

6.2.1 Making personal links to the scientist and their work

Visitors indicated, in post-session and delayed post-session interviews, that they had formed links between their own interests and experiences and those of the scientists and their research. Comments demonstrating that visitors had identified with scientists in this way were grouped into four categories stemming from the iterative coding of transcripts (see Table 3):

- Relating to visitors' life experiences and interests;
- Relating to visitors' job or study;
- Relating to places;
- Relating to visitors' personality and personal life.

For each group, comments were made by visitors in both post-session and delayed post-session interviews, demonstrating that the connections and identification with the scientist and science topic were relatively long-lasting impacts.

i) Life experiences and interests

Twenty visitors mentioned their own personal life experiences and interests when making links to the scientist after meeting them. The following quotes were from two Australian women who attended a session on Australian mammals. During the session, the scientist had mentioned animals that the women had encountered when they were younger:

Interviewer *So what did you think was the best bit?*

Miss L *I think the platypus actually, I'd kind of forgotten about it as well, you don't see them in the wild, so seeing it up close is really cool.*

Anna *I think they've only got them in the zoos, they're the only place you would see them, you would never see them in the wild, like, the koalas you walk past and you're like – oh look a koala. And kangaroos they jump past all the time, like, we used to look out the window at school and see kangaroos jumping.* (NL-S, post-session interview)

To give another illustration, one of the example case participants presented in Chapter 5 also made connections between her experience in her garden and the slugs the scientist had spoken about:

Amelia *I mean, when I think up in Scotland we used to have these huge, what are they called leopard or tiger slugs, I can't remember now, leopard ones, and I used to shovel them up with a shovel and throw them over the fence at the bottom of the garden. And now I think they were doing good – you want them around!*

They weren't eating my vegetables at all! (NL-Zk, delayed post-session interview)

Visitors saw similarities between the work and life of the scientists and their own experiences and interests. Sessions often prompted visitors to recall previous life experiences or to return to interests they previously had.

ii) Job or study

Thirteen visitors made connections between the scientists and their own work or study. This visitor relates the work of scientists studying and preserving specimens to her own experiences of learning biology:

Nancy *And that's perhaps one question – how are they being studied, because they are so precious, you know preserved, how are they actually being studied. Because they can't be sort of probed and dissected in the ways sort of, well in my O-Level biology we used to*. (NL-T, post-session interview)

Other visitors identified links between their own careers or current study and the work of the scientist. Comments in this category came not only from visitors who were scientific researchers themselves or who were studying in a science area – visitors in non-science careers also identified similarities between their own work and that of the scientist. For example, the following visitor (who worked in research but not in a scientific field), one of the example cases from Chapter 5, empathised with the challenge faced by the scientist in explaining her work to a non-specialist audience:

Laurie *I can really appreciate how difficult that is because my job when I explain to people in industry about what my company does communicating to people who have no idea about it – I think she did a really excellent job.* (NL-Zq, delayed post-session interview)

Kate, who was a teacher (a further example case individual presented in Chapter 5), talked about how she picked up some ideas from the scientist's presentation on how she might teach the topic of volcanoes to her own class:

Kate *I really liked how he, when he got the stick and just how it breaks. And I might be able to do that with my class when I'm explaining that to them. So I've got some ideas about how I can explain it to children, so that was good.* (NL-L, post-session interview)

This visitor, who was a research scientist himself, compared his own presentation style to that of the scientist and identified where he might have learned something from the scientist about his own work:

Martin *I think it was nice to see the way science is presented actually. I think it's much more creative than our, sometimes more didactic teaching we do, and then it's something that we can take away and have more multimedia presentations.* (NL-E, post-session interview)

iii) Places

Visitors identified with places that the scientists mentioned, commenting that they had been to sites the scientist had visited for field-work, or explaining that they lived close to a place the scientist spoke about. Nine visitors commented in either the post-session or the delayed post-session interviews that they were making connections to the scientists and science through the places mentioned. The visitor below attended a session on volcanic islands. She later talked about how the session had made her reconsider Barbados, where she was born:

Aladdin *I can relate to, you see, with Barbados, another little island in the Caribbean, wondering whether it is similar. Because I do walk around the coast and all that, you see and explore. I was trying to draw a comparison, draw a parallel between these two islands.* (NL-Zo, delayed post-session interview)

For other visitors, the sessions reignited memories of places they had visited previously. Patrick, one of the example cases from Chapter 5, remembered how he had visited Lyme Regis, a place mentioned by the scientist in their session about hunting for ammonite fossils:

Patrick *Because actually we've been down to Lyme Regis with friends a couple of years ago, on the beach digging around and I was wracking my brains back*. (NL-Zz, post-session interview)

These comments indicate that visitors were aware of the experiences they have shared with the scientists, again helping to identify more closely with them.

iv) Personality and personal life

Finally, visitors identified connections between themselves and the scientists in terms of identifying similar personality traits, or seeing links to their own families and lives. Eight visitors made comments in this category. For example, this visitor connected with the scientist through their similar accents:

Mildred [The scientist was a] *Northerner, which I like because I'm from the North, and I like the fact that he had a Northern accent rather than an Oxbridge* [sic] *or Cambridge type, which is what you would normally associate with some scientists.* (NL-G, post-session interview)

This visitor explains how the presentation style of the scientist had connected with her own preferred way of learning and her interests:

Waffles *Well I'm a very visual person because I'm an artist and anything that's got a picture interests me. A number of words I might find interesting, but you know they don't excite me, but when she showed pictures of, they're not called crystals, I forget what they are called, the bits of rocks that fall to earth, that's what I found exciting.* (NL-O, delayed post-session interview)

This quote from Waffles is of particular interest as it exemplifies where the visitor has not remembered some of the science content of the session – the names of the meteorites or 'bits of rocks that fall to earth' – but has identified with the scientist and their presentation style. This case poses the question as to whether an individual can fail to identify with science content but successfully identify with an individual, and, therefore, what does that mean for scientific literacy? From the case above, it would seem that an individual may identify with a scientist but not the content they were talking about to the same degree. Although this might present a problem in terms of developing scientific literacy initially, identifying with a scientist may promote science engagement and literacy further in the longer-term – individuals may be more likely to engage in future science activities as they see connections to those delivering them.

Previous work has shown that identifying with scientists on a personal level is an important outcome of face-to-face interactions with scientists. In a study into role models for girls in science, 13-14 year-old girls valued knowing about the personal background of the scientist in order to identify them as role models and become more connected to the scientist (Buck *et al.*, 2008). The personal background of scientists would include aspects of their personality, life experiences, work and places visited, relating to the findings in the current study.

The findings discussed above demonstrate how visitors make links to the scientists as a result of meeting them at Nature Live events, drawing from different elements of their own lives to make these connections. Visitors identified more closely with the scientists and their science as a result of the sessions, with these impacts lasting at least two months after the visit for some visitors.

6.2.2 Forming new links with the subject

A smaller group of visitors formed *new* links or associations to the subjects or the scientists they had encountered, rather than identifying connections through previous experiences or existing similarities, as discussed above. In post-session and delayed post-session interviews, 16 visitors reported not having thought about a particular concept before, or indicated that the way the scientist had presented their topic had given them a new insight into the subject. These new insights and perspectives often led the visitor to report feeling closer to the subject and the experiences of the scientist. The visitor below described how it was the way the scientist presented their topic that enabled him to make new connections and develop new interests in the area, compared to other learning formats such as books:

Tino *Well the subject was brought closer to me in a different way, more interest, more I felt, not just looking at a programme or reading a book, but more like, into the part of the subject*. (NL-M, delayed post-session interview)

In terms of forming new links to the subject area, visitors also indicated that the session had had an impact on their interest in the subject itself. There are subtle differences between these two themes – the first theme, concerned with forming new links to the subject, is about feeling closer or more connected to the subject, whereas this theme is purely about impacts on interest. Interest may, in fact, result from a new link or connection to the subject and, therefore, the themes are related. In post-session and delayed post-session interviews, 27 visitors mentioned how the session and meeting the scientist had an impact on their interest in the subject and the work of the scientist.

Fifteen visitors indicated that the session had sparked a new interest in something they had not previously been interested in, for example:

Lyn *Yes it made me feel very differently about seaweeds. They are not these annoying things you have to walk around, avoid, exactly, so very complex things that you can use for all sorts of purposes. And I didn't realise that at all. So this has really opened my eye to it. That was very interesting.* (NL-Zv, delayed post-session interview)

Of the comments relating to interest, nine visitors stated that the session had added to a pre-existing interest and had increased their interest in the subject in some way. For example:

Elvis *More interest in – I've always been interested in these kinds of programmes, nature and things, but they make you more interested in animals and what they do and what they are, and how they kind of help each other, or link to us.* (NL-Za, post-session interview)

Three further visitors who had a pre-existing interest in the subject, including Pat – an example case from Chapter 5, mentioned that the session had maintained their interest, neither increasing or decreasing the interest they held for the topic but keeping them interested:

Pat *What did I get out of it? Again just topping up, filling up areas that, in things that I'm interested in anyway. Yeah, just little pieces here and little morsels here and there, that keep me interested and make me feel to want to find out more along the way, keep me interested.* (NL-P, post-session interview)

Only one visitor mentioned specifically that the session had not sparked a new interest in the subject. This lack of impact on interest may have been the case for more visitors, but they did not express it in their comments in the interviews. No visitors reported that attending the session had reduced their interest in a subject.

Finding that some visitors demonstrated a new or reinforced interest as a result of the session is important, as interest is a way in which science may link to their everyday lives. Sparking a new interest, for instance, may mean that the visitor is more likely to pay attention to the topic; visitors know they find the topic appealing and may, therefore, be more likely to engage with similar sessions in the future. Reinforcing or broadening an existing interest is also important, as interests require repeated engagement and support if they are to become sustained and long-lasting (Hidi & Renninger, 2006). Using Hidi and Renninger's (2006) four-phase model of interest development, Nature Live sessions may spark a new triggered situational (short-term) interest, reinforce a short-term interest and enable progression into a maintained situational interest, or aid development of a personal interest – a deeper and more developed level of long-lasting interest. Interactions with scientists, therefore, have the potential to have both short and long-term impacts on interest, creating links and connections between visitors and the scientists and scientific topics they encounter.

In connecting science and the work of the scientist to their own lives, visitors are likely to see science as more relevant and interesting, not as something disconnected from their own hobbies, lives and values. Seeing science as part of everyday life is important in enabling individuals to engage with science in the future. Zimmerman and Bell (2012) reported that students made connections between science and the things they did at home, school, in their community and media environments when opportunities allowed for students' own definition of science to be taken into account. When asked to define what they thought to be science and not science, students were able to link science with other experiences and opportunities, encouraging participation with science and future learning. Interactions with scientists, therefore, such as those studied in the current research, may benefit from opportunities for linking to visitors' everyday lives and own ideas about science, in order for individuals to see science as more relevant and interesting.

Costa (1995) interviewed 43 students to study the relevance of science to students in terms of the congruence between the worlds of school science and the students' family and friends. Students who indicated that the worlds of their family and friends were more congruent or compatible with the worlds of school and of science were more likely to be planning a career in science. Costa argued that school curricula need to enable students to see the relevance and importance of science to their personal lives and society and break down barriers between the worlds of school and science and students' friends and family. The fact that visitors in the current study were able to make links between the scientist and their own lives and experiences suggests that visitors may have felt encouraged to engage with science in the future and develop their scientific literacy further.

6.3 Social positioning and distance

In order for visitors and students to be able to identify with scientists they must perceive there to be minimal social distance between themselves and the scientist. Psychological distance describes how closely items are perceived to be in relation to the individual (Bar-Anan, Liberman, & Trope, 2006; Baram-Tsabari & Yarden, 2009). Objects, individuals, events or ideas can be psychologically distant from an individual in terms of: space (spatial); time (temporal); social nature and familiarity (social); and how likely the event or item is to materialise (hypothetical) (Bar-Anan *et al.*, 2006). Social distance is explored below to establish whether participants position themselves as more or less psychologically distant to the scientists after meeting them. Perceiving oneself as less distant from another individual could be an element of identifying with that individual as a member of a common group (Holland *et al.*, 1998).

6.3.1 Positioning in relation to scientists

The quotes and discussion presented in the sections above demonstrate how visitors connected with the scientists and their subjects by identifying links between their own experiences and interests and those of the scientist. These findings were drawn from interview data where visitors themselves explicitly identified and expressed the links they had made to the scientists.

Another analytic perspective enables the study of more subtle clues that visitors were identifying with scientists. In exploring how visitors positioned themselves in relation to the scientist and the rest of the audience, it can be argued that visitors were connecting more or less with the scientists themselves. In post-session and delayed post-session interviews, 12 visitors made comments which positioned the Nature Live visitor as separate to the rest of the audience or other members of the public. Examples of these types of comments, including one from James N – an example case individual from Chapter 5, are:

Chris — *That's why we were hoping to find, just those little few things that you don't find in literature, but then again that probably would be too much for the average visitor wouldn't it?* (NL-K, delayed post-session interview)

Wendy — *You almost kind of forget about nature. I know it sounds awful because it is all around us, and we are quite good as a family. But I think people in general do* *tend to forget about the nature that is around them.* (NL-Zl, delayed post-session interview)

James N *Maybe he could have gone more into which, you know rather than just a selection of insects he could have talked about who eats them, what they eat, what they normally do, you know that sort of thing, gone a little bit more in depth. Because it maybe wasn't targeted at me, so it's difficult to say.* (NL-Zx, delayed post-session interview)

By positioning themselves as apart from other members of the audience, it could be argued that visitors were relating more closely to the scientist they met, aligning themselves to the scientist and what they spoke about. This conclusion is plausible as all 12 visitors making comments in this group mentioned that they would have liked more detail, more of the scientist's own perspectives, or could have handled more in-depth scientific information than other audience members or 'members of the public'. These are all responses that placed the visitor closer to the scientist than the other members of the audience they referred to, rather than further away. The fact that these comments did not arise in pre-session interviews, but after the experience of meeting the scientist, suggests that positioning closer to the scientist was a result of the interaction, rather than a pre-existing bias in the audience.

An alternative explanation might be that the pre-session interviews themselves had influenced the participants, and that their responses following the session were the result of them being more aware of the focus of the current study and prompted to think more carefully about their perceptions and attitudes towards the scientist. However, I would argue that the effect of the pre-session interviews is minimal, as the comments about positioning in relation to the scientist were all made within answers to other questions, almost as additional points or asides. The comments about positioning in relation to the scientist were not in direct response to a question from the interviewer, but made almost spontaneously, and in this way are less likely to be the result of awareness of interview topics or bias because of pre-session interviews.

The visitor in the following quotation explained how she had some understanding of the subject before the session. Bridgit was a first year undergraduate biology student, so was more knowledgeable in science than the average visitor but identified even more closely with the scientist during the session, resulting in her positioning herself as closer to the scientist than the other audience members. After seeing other members of the audience struggle with the scientific content, she positioned herself apart from 'the public', adding how she had adopted the role of an expert and helped answer a question from a fellow audience member:

Bridgit *I liked the fact that the public kind of got involved with the talk and they were interested to know about this, you know sort of the people who hadn't thought about ocean acidification as a problem and hadn't heard about it. So I know some of the girls beside me were talking about it. And then the gentleman beside me asked me about, 'Is CO_2 a natural acid?' and I was explaining that it was a gas that reacts with water and it's what then produces an acid – it's reducing the pH.* (NL-W, post-session interview)

In seeing and talking about themselves as closer to the scientist and the subject and identifying common areas of interest, visitors may be more likely to see science as personally relevant and as something they would engage with later on. Of course, some people may already explicitly identify with science – such as Bridgit, above, who was studying for a science degree, however, meeting the scientist enabled her to identify more closely with one of the Museum scientists and build her membership within the community of science. This process of identification helped the visitor to see scientists as 'people like me', relating to some of the descriptors of scientists discussed in section 5.4, such as being relaxed and informal, friendly, approachable and 'normal'.

The importance of developing links to the person behind the science, or portraying science as a human endeavour, conducted by 'people like me', is recommended by the researchers involved in the ROSE study. These researchers stress that seeing science as a personal and human activity, part of history and culture, is the basis for embarking on jobs in science (Sjøberg & Schreiner, 2010). Visitors in the current study appeared to be identifying with scientists more closely, alongside new or increased interests relevant to the work of the scientist. These impacts may signify that visitors are more likely to engage with similar content in the future, therefore promoting future scientific literacy and engagement.

6.3.2 Evidence from field-notes: opportunities to identify with scientists

The context may have contributed to visitors identifying more closely to the scientists they met. For example: the content of sessions; delivery by scientists and hosts; and the set-up of the interactions may have influenced how the visitors identified with the scientists. Analysis of field-notes from the sessions enabled these contextual contributors to be identified. There were mentions of social positioning of visitors and students in relation to scientists in the field-notes from 29 Nature Live and seven A-level day events.

Comments in field-notes from 11 Nature Live events and three A-level events related to deliberate efforts to identify connections between the scientists and the audience during sessions. Questions were posed to the audience by the scientists or hosts in an attempt to illustrate shared experiences or interests and scientists compared their equipment or research to things that were familiar to the audience members:

> *Robin asks the audience if anyone has been to Borneo themselves and a few people put up their hands.* (NL-N field-notes)

> *Tim explains the equipment he uses to collect the samples, comparing it to things you might normally take to the beach.* (NL-Zr field-notes)

The audience were also invited to become involved with the work of the scientist or were told about opportunities where they could act in the role of a scientist. These types of comments were identified in field-notes from 13 Nature Live sessions and four A-level events. These comments acted to close the distance between audience members and scientists, as audiences were invited to share experiences with the scientist:

> *This comment leads Fred to talk about the Bluebell survey they have launched, a way in which the audience can help with the research. They show the website, talk about the kinds of information they are looking for and encourage the audience to keep an eye out for the first flowering bluebells and log them on the website.* (NL-Zp field-notes)

> *Cameron introduces a case he wants the audience to help him solve – and presents them with some information and a graph to do this.* (AL-G field-notes)

The majority of mentions about social distance from the field-note data indicated a decreasing distance between audience and scientists within the session. There were occurrences, however, which positioned the scientist as more distant from the audience. There were mentions of this type in field-notes from five Nature Live events – creating a barrier between audience members and scientists, or portraying the scientist as more distant:

> *Maurice* [host] *says* [in response to a question from a visitor] *that he likes the way that 'us non-scientists just want to know whether it's alright or not' and want to hear that it is a good thing*. (NL-K field-notes)

> *Laura* [scientist] *talks quite quietly and nervously at times, she faces Isabelle* [host] *throughout the majority of the event, not really engaging with the audience. There are also quite a lot of complex terms.* (NL-Zf field-notes)

In general, events provided opportunities in which the social distance between scientists and audiences was closed. These data from field-notes, therefore, support the interview data in which visitors positioned themselves as more closely aligned with the scientists and identified more closely with the individuals they met, compared to before the session. What follows is a discussion of how the sessions also led students to identify more closely with the scientists they met.

6.4 Making connections: identifying with science careers

Students identified more closely with scientists following the Nature Live session whilst considering their own career options. This section specifically focuses on how students identified with the scientists as potential models of those in science careers, whereas section 7.3.3 discusses the potential long-term impacts on engagement with science in terms of students' perceptions of, and attitudes towards, science careers. This section outlines how students made connections to scientists through exploration and discussion of careers in science.

The A-level 'behind-the-scenes' day is marketed to teachers and students as follows:

> *This exciting day aims to inspire students about working in science and to provide real examples of biology in use. Students meet Museum scientists and find out about their work, participate in a taxonomy workshop and witness the scale of our collections on a tour of the zoology research and storage facility in the Darwin Centre.* (Natural History Museum, 2013a)

The students are likely, therefore, to be arriving at the Museum prepared to explore information around scientific careers. Although encouraging students into science is an important aspect of science communication and education, it is not the main focus of the current research. Instead, the research is focused on increasing scientific literacy and engagement more generally, although the desire to pursue a scientific career may be one outcome of the experience. Because the students were just about to make decisions regarding higher education or future work plans, questions about careers were included in the interview schedule and students often mentioned science jobs in answers to other questions. In contrast to the adult visitors, students identified links to the scientists they met around the topic of science careers and jobs, as opposed to more generally about their lives, experiences and places they had visited.

6.4.1 Student career plans

The students attending the behind-the-scenes days were an interested audience already; they had all opted to study AS or A-level biology. It is likely, therefore, that the students interviewed may have been considering a career in science, or at least enjoyed learning about science. Students were asked about their plans for future study or work after college in pre-session interviews[12].

All the students interviewed were considering going to university; some students had already decided on the subject(s) they would like to study. Thirteen students had decided that they would like to study medicine and 12 more said that they would like to study something in science but not medicine. One of these students said she would like to study pharmacy; another student was sure he wanted to study for a phylogenetics course at Reading University. Other students knew that they would like to study science but were not clear on the specific subject at the time of interviews. Three students wanted to study subjects not within science, including law. Finally, 10 students were not sure what they wanted to do after A-levels; university was a potential option and they were not sure whether or not their subject choice would involve science. The example case student we have returned to throughout the findings chapters, Betty Boop (AL-C group), knew she would like to study science but was not sure yet what subject. She was clear that she would like to go to university to study ‘something about science’, but had not narrowed her options beyond that.

[12] Where there was no pre-session interview for groups AL-D and AL-E, students were asked early on in the post-session interview what they had been considering to study further or to take up as a career, before they came to the Museum.

6.4.2 Students identifying with scientists

Through identifying more closely with the scientist they met, students were able to develop their understanding around science careers whilst 'modelling' the scientist, comparing themselves to the scientist to see if a science career was for them. Eighteen students indicated that the stories and experiences shared by the scientist had led them to think differently about science and science careers, mostly (all but two students) in a positive way:

Louis Pasteur — *I think that the story she had about wanting to go into medicine, but not being, not quite getting enough to go into medicine, it shows that like, it's not the only thing, there is other opportunities, if you, if you don't do really well.* (AL-B group, post-session interview)

In contrast to the majority of students, the student below describes how her exposure to science jobs at the Museum confirmed that this was not an area she would like to pursue as a career:

Hannah — *It got a bit, well when someone asked her what she was doing, you know when she was sitting at her desk, for what 24 grand a year and she was looking at databases, she didn't seem that happy. But obviously it does make her happy and it is important for the plants, so it was interesting to hear about what she does. But not in terms of me wanting to go into it.* (AL-A group, post-session interview)

This student identified less closely with the scientist following the meeting, describing how her own interests were not aligned with those of the scientist in terms of jobs. Such an impact is important in terms of portraying a realistic image of science and science careers, be that positive or negative, so that students can make informed decisions about their options for the future. Hannah, above, for example had been considering a science career and further study in science, but was not sure at the time of the study exactly which direction to choose. Experiences which portray a realistic image of science jobs, therefore, are useful in helping make informed decisions.

Seven students also made specific references to how the interaction with a scientist and the resulting increased understanding and awareness about science jobs had an impact on their own attitudes. Students identified with particular parts of the scientists' job thus developing ideas about their own careers. Impacts on the students' career plans are explored further in section 7.3.3 but examples are provided here of how identification with scientists around elements of their job (fossils and fieldwork in the examples below) triggered impacts on students' own attitudes:

Newton *Yeah I think that a lot of students who are good at sciences, they sort of assume that medicine is the only career path, and I'd definitely consider sort of working with fossils now* (AL-B group, delayed post-session interview)

Walrus *Well it definitely makes me think that pursuing science as a career is not as bad of an idea as what I used to think! Yeah!*

Interviewer *And relating to that, I asked you before, what were you planning on doing after college?*

Walrus *Still probably something science-y, but I thought, something less fieldwork-y. But now I really want to do something field-work-y after this.* (AL-C group, delayed post-session interview)

Scientists and hosts invited the audience to become involved in the work of the scientist. Being invited to become involved may have facilitated student identification with scientists. This type of invitation may act to close the perceived distance between the audience and the scientist. Responses from 14 students illustrated impacts of these invitations on their attitudes to science and intentions to participate in science in the future:

Sophie *I wouldn't mind volunteering in the plant project.* (AL-A group, post-session interview)

Shaniqua *And showed us step-by-step how it works and even explained that sometimes they even have people coming in at A-level to just, like, work experience, that was quite interesting.*

Sampson *That's something I'd like to do.* (AL-F group, post-session interview)

The findings indicate that students identified with the scientists, making links between the jobs of the scientists and their own career plans and attitudes towards jobs in science. Students may be exhibiting ‘wishful identification’ towards the scientists, defined as ‘a desire to be like or act like the characters’ (Hoffner & Buchanan, 2005, p. 325). Wishful identification has been studied in teenagers identifying with scientist television characters, using statements such as ‘I would like to do the kind of things that he/she does…’ to demonstrate wishful identification (Steinke *et al.*, 2012). Intelligence has been identified as a being a factor which predicts students’ identification with television characters; a high level of intelligence of characters predicted more wishful identification (Hoffner, 1996; Hoffner & Buchanan, 2005; Long *et al.*, 2010; Steinke *et al.*, 2012).

The influence of intelligence in wishful identification identified in studied by Hoffner and Buchanan cited above, links back to the descriptors used by participants in the current study when referring to the scientists they were expecting and later met. Students were expecting scientists to be intelligent, knowledgeable and experts in their field, see Figure 17. However, students became relatively less likely to describe scientists as knowledgeable experts following the session, compared to other descriptors. This finding contradicts the work into wishful identification with scientists in which the perceived intelligence of characters is shown to be an important predictor of student identification with the character. It may be that other descriptors play a more significant role in whether or not participants identified with the scientists they met in the current study – for example descriptors such as passionate, enthusiastic, interesting, engaging, approachable and nice were used more frequently by students to describe scientists after meeting them compared to before. Discrepancies between the current study and the work of researchers such as Hoffner, Long and Buchanan cited above may be explained by the fact that students met scientists face-to-face in the current study whereas the work into wishful identification focused on media characters. The current study may, therefore, contribute to the understanding of the attributes important in facilitating identification with scientists following face-to-face interactions.

Individuals such as parents, teachers, and in this case, scientists, may act as models and definers, using Woelfel and Haller’s (1971) work around significant persons. These individuals can be inspirational for career choices in science (Sjaastad, 2012b) and may influence attitudes towards science (Sjaastad, 2012a). Models provide a template and a reference to which to refer when considering the responsibilities, challenges and rewards of a certain career. Definers allow students to explore how they feel about the role and define themselves in alliance with the career path, for example, asking questions about what it is like to be a scientist and how you might study towards being a museum botanist. The model of significant persons illustrates how Museum scientists may have influenced the students they met in terms of attitudes towards science careers. There may not be enough time or intensity of interaction for a role modelling relationship to develop between scientists and visitors or students, but scientists may still act as examples and references to which visitors and students can identify more or less closely.

In making connections to scientists around careers, and responding positively to invitations to participate in the work of scientists, students may have been imagining themselves in the role of a scientist. A study into the impact of an undergraduate programme involving a research investigation, in which students and university scientists worked collaboratively, highlighted that the experience confirmed and clarified students' intentions to continue with a science career, in which 'seeing myself doing this' was indicated to be a crucial aspect of this process (Hunter *et al.*, 2007). Similar impacts have been seen in teachers taking part in a mentorship summer programme with scientist mentors: the programme increased teachers' sense of membership in the science community and their ownership and understanding of scientific enquiry (Hughes *et al.*, 2012). These findings mirror the impacts of meeting scientists seen in the current study, where students asked questions and made comments suggesting they were exploring what it would be like to be a scientist, specifically one working within a museum community.

It is important that students not only appreciate the importance of scientific research, but also see science as personally relevant and interesting. By seeing science as a potential career option that is attractive and suited to them personally, students may be encouraged to pursue science further. Jenkins and Nelson (2005) report how students aged 14 and 15 rated science as important and interesting, but that students did not aspire to have a career in science themselves. Similar findings emerge from the ASPIRES project. Students often rate science as enjoyable and positive but decide from an early age that science is not for them, resisting adopting a science identity of someone who may pursue a science career in the future (Archer *et al.*, 2010; DeWitt *et al.*, 2013). The current research provides support for using interactions between students and scientists as one way in which careers in science may be seen as personally relevant, appealing and attractive.

6.5 Interest development: asking scientists questions

A closer identification with a scientist may be facilitated by increased interest. Interest is related to a particular content area or subject, and results in a desire to know more about the object of interest and engage further with it. In this way, asking questions is an indicator of interest, of a desire to learn, and an act of engagement with the subject (Chin & Brown, 2002). The topics of visitors' questions may, therefore, indicate areas about which they are most interested and want to learn more (Baram-Tsabari, Sethi, Bry, & Yarden, 2010; France & Bay, 2010). Through asking questions about particular topics during interactions with scientists or in interviews and conversations about the session, individuals are revealing an interest in the focus of those questions. Questions about the scientist themselves indicates an interest in the person the visitors met and their work. Questions about the scientific topic of the session would indicate an interest in the particular session focus, which would be a common interest shared with the scientist. A shared interest with the scientist they met, or an interest in the scientist themselves, suggests that visitors and students are becoming motivated and engaged with science, identifying more closely with the individual scientist.

To study any trends in the interests of the students and visitors, the content of the questions they generated was examined. Students and visitors were asked what questions they would like to ask the scientists and what they wanted to find more about from the scientists they met. Participants were asked about their questions before meeting scientists, in pre-session interviews, and afterwards, in post-session and delayed post-session interviews. There was no limit placed on the number of questions visitors and students could give. I prompted for more questions or other areas the visitor was interested in until the visitor stated that they had mentioned all of the questions they could think of.

The codes used to explore the overall topics of student and visitor questions before and after meeting scientists are given in Table 12 (following France & Bay, 2010), with examples of questions asked. There were 12 questions that did not fit the categorisation in Table 12. One question was about the Museum itself and what proportion of the collections was open to the public. The other 11 questions were classified as 'other' and were not to do with the Museum, science, scientists, or the experience of the meet-the-scientist session. These questions were often asked humorously, for example, one question before a session on meerkats included 'is it quite difficult training them to sell insurance?', referring to a television advert from a UK insurance company in which meerkats are shown running the business. The initial inter-rater reliability between two coders was 85% for the A-level student question data and 83% for the adult Nature Live question data; any differences were resolved through discussion until 100% percentage agreement was achieved.

Table 12. Question coding frame (describing the topics students and visitors were interested in asking scientists about, following France and Bay, 2010).

Category	Description	Examples	Total occurrence (visitors)	Total occurrence (students)
Personal	Questions about the scientist themselves, their career history and life as a scientist	'And what kind of things did they, like, study. And when did they make the decision that that was something they wanted to, like, specialise in?' 'Also how did you become, go from a scientist to, like, when did you decide to work in the Museum? And not just in a lab?'	85	78
Science information	Questions about scientific concepts, facts and phenomena	'What kind of algae is there - it all looks pretty algae-y to me, but is there colourful algae, living, like, algae that eats things?' 'Insects and bugs are they the same thing or are they different?'	346	61
Science process	Questions about scientific research, how science is carried out and techniques and methods	'I would like to hear how people classify new animals/organisms, and the criteria for doing so' 'Could you ever find out how much a dinosaur fought from its bones?'	66	44
Social and ethical issues	Questions about issues in science and scientific research relating to science and	'Is there any opposition to the work that you are doing, you know if someone wanted to build on the site of a plant which was at risk?' 'And stuff about the fragmented	39	9

	society, culture and moral and ethical dilemmas	parts of the Soviet Union, so not directly to do with her work, more to do with the environments that are going on there, and how that stuff [science research] works over there?’

Questions from the four data collection points (pre-session interviews, during the session, post-session interviews and delayed post-session interviews) were analysed according to topic. This procedure allowed the trends in what the participants were interested in asking about to be explored over time. The frequencies of questions asked at each point, arranged by topic category, are illustrated in Figure 19 for visitors and Figure 20 for students. It should be noted that questions from the participants were analysed for the questions generated within the interviews but questions from the entire audience were analysed for the session itself. This inclusion of questions from the whole audience explains why there were more questions asked during the sessions, compared to the other time periods. Data from the entire audience were included as participants in the pilot study often mentioned that their questions had ‘already been asked’, or that other members of the audience had asked about the thing they had been wondering. Including the questions from the rest of the audience maximised the potential data available on the topics of visitors’ and students’ questions. The data are presented from the entire sample in Figures 19 and 20 to provide illustration of trends operating across the group of individuals sampled. This global perspective of analysing the data complements the individual level of analyses presented thus far in this chapter. The patterns identified at the global level are then also supplemented below by the presentation of individual cases who illustrate the key trends.

Figure 19. Questions generated by visitors to ask scientists, by topic and data collection point (n = 536).

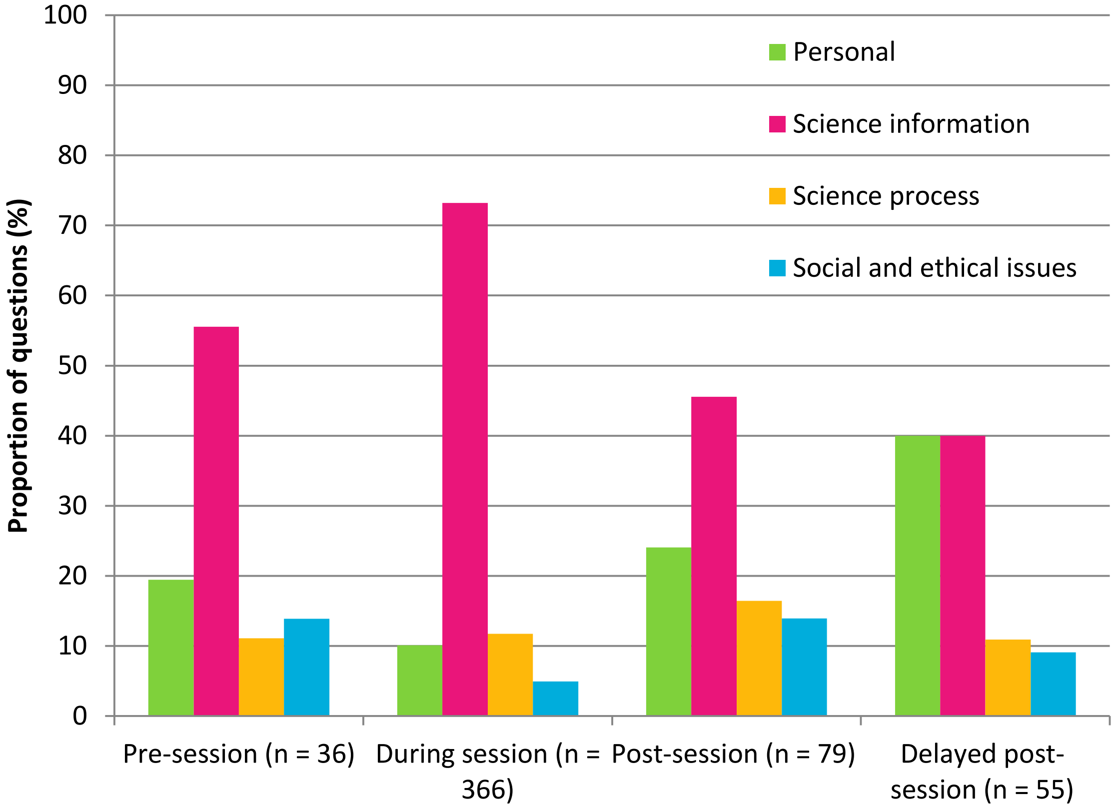
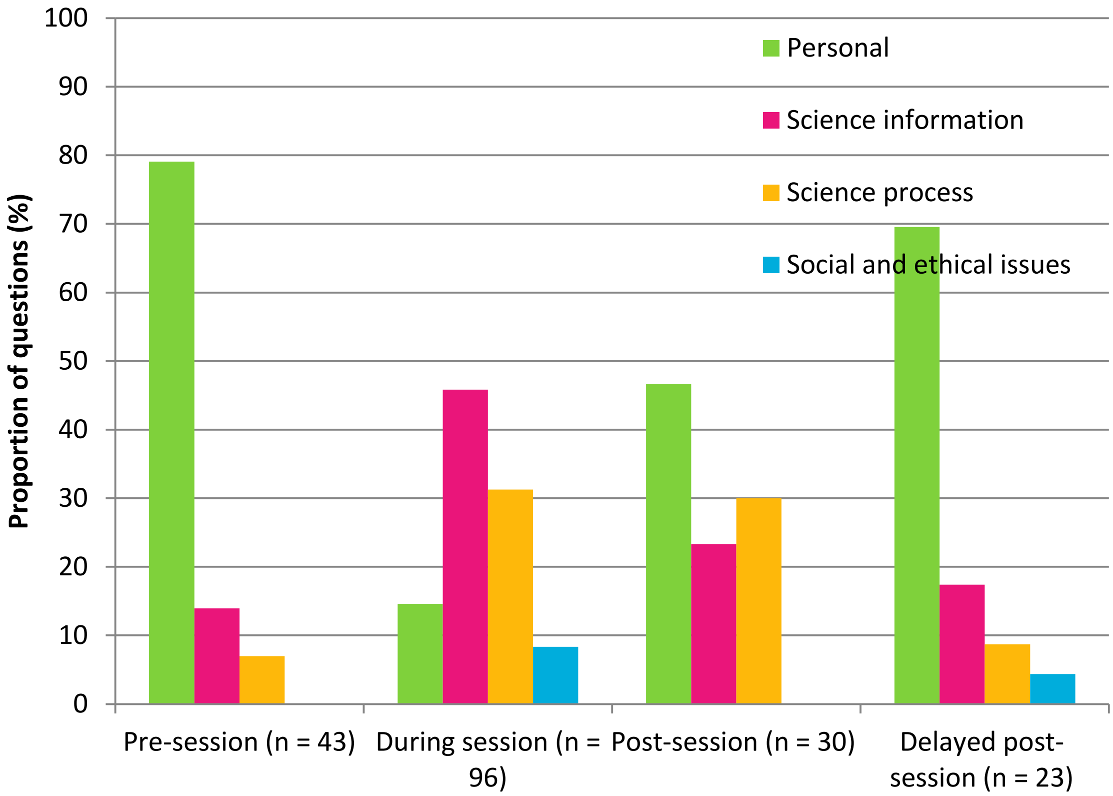


Figure 20. Questions generated by students to ask scientists, by topic and data collection point (n = 192).



6.5.1 Trends in questions from Nature Live visitors

The predominant topic of questions from Nature Live visitors across all time slots was the science information – the scientific content of the sessions, for example 'What do all bees have in common?' The interest in the scientific topic, however, decreased after meeting the scientist and even more so in the months after the museum visit. In contrast, the proportion of questions asked about the scientist personally increased, including those about the scientists' day-to-day life and personal experiences, for example, 'How did you end up specialising in parasitic wasps?' Visitors seemed to become relatively more interested in the scientists themselves and less so in the scientific content of the session. Two examples are presented below of visitors who had questions about the scientific content of the session in pre-session interviews, but had questions about the scientists personally in interviews after the session:

Pre-session:

George *Basically how long the Hubble is going to remain being in service, because I had heard that it was more or less for the last time*. (NL-U, pre-session interview)

Post-session:

George *Well the first thing I would ask him would be, what's your current research? And how is that coming along? That's the missing link really, he was really giving a general spiel, and sometimes when you come to hear a scientist you really want to hear what he personally is doing.* (NL-U, post-session interview)

Pre-session:

Candy *I would hopefully find out why particularly whale bones, are they a particularly nourishing source?* (NL-Ze, pre-visit interview)

Delayed post-session:

Candy *Well I know he was going to go on that other trip – I just wanted to know how that all went really?* (NL-Ze, delayed post-session interview)

Laurie, one of the example cases from Chapter 5, is an illustration of someone who did not have any questions before the session but who developed interests in the scientists personally following the session which remained in the delayed post-session interview:

Post-session:

Laurie *I'm thinking to myself, what is she going to do after she finishes her post-doc? That's what I'm interested in – is she going to go on to teach, or a hobby or what?* (NL-Zq, post-session interview)

Delayed post-session:

Laurie *I guess I would ask her, when I was watching it I was curious, what her aspirations are next? Will she continue to find new species from the Cambrian, or what does she want to do, does she want to teach, does she want to continue to do her research? How long can you continue to study one particular species? So I, that's what I found quite interesting, she has quite a lot of options ahead of her. So more about her as a person.* (NL-Zq, delayed post-session interview)

Other question categories included those about scientific processes – how scientific research is carried out, for example 'Is this the only way of conserving them, or can you freeze them [specimens]?' and questions about science in society and social and ethical issues around science, for example 'How does the research done on Mars help the human kind, or humans?' Proportions of questions in these categories remained relatively stable across each time period; the frequency of these questions did not change relative to the frequency of other questions asked. It is concluded that there were limited impacts of meeting scientists on visitor interests in these areas.

The increase in proportion of personal questions about the scientists is interesting when considered alongside some of the other impacts of meeting scientists identified earlier. An increase in the proportion of questions asked about the scientists themselves suggests a shift in interest from the scientific content to the scientist. This pattern complements the findings about visitors making links to the scientists, seeing themselves as more closely aligned with the scientists and identifying common areas of interest and shared experiences. Visitors appear to have become more interested in the people behind the science through changing perceptions of scientists and identifying links between themselves and the scientists. The increased proportion of questions in this area may be one way visitors tried to find out more about the scientists in order to understand and link to them further.

I argue that the differences in question topics after the session compared to before are the result of the interaction with a scientist having an impact on the areas in which visitors are interested. An alternative explanation might be that there was an effect of the pre-session interview on participants and their responses in later interviews. The pre-session interviews would have alerted participants to the fact that I was interested in hearing what questions they had for the scientist, and might ask them about their questions again later. However, I argue that the impact of the pre-session interviews on the findings on trends in questioning was minimal. The pre-session interviews may well have encouraged the participants to consider their questions more closely than had there been no pre-session interview. However such an influence would have only led participants to think through their questions more carefully, perhaps generate more questions, but is unlikely to have influenced the topics participants asked about. The trends in question topics, therefore, are likely to have been influenced by other factors such as meeting the scientist and the session itself.

6.5.2 Trends in questions from A-level students

Students arrived at the sessions with many questions about the scientists, their jobs and how they got into science. During sessions they became more interested in the science content and scientific process. Two months after the visit they returned to being more interested in the scientist themselves and the job of scientists, with this category containing the highest proportion of questions in the post-session and delayed post-session interviews.

The following interview extracts from Alice and her fellow students in group AL-A, who attended a session about forensic science, provide an example of how the topic of questions changed over time, from questions about the scientist before the session, to questions about the scientific process immediately after the session, and back to questions about the scientist personally in the delayed post-session interview:

Pre-session:

Hannah *And kind of what got them* [scientist] *into it* [field of study]*, what they did before?*

Alice *Yeah what they did at university?* (AL-A group, pre-session interview)

Post-session:

Alice *The temperature thing, it wouldn't be, I don't know how accurate it would be because if the person was found down the side of the building, and he'd been* *there for a month or something, so wouldn't the temperature have changed, you know in those months?* (AL-A group, post-session interview)

Delayed post-session:

Anna *Maybe just a bit more about how they got into their career, what they kind of did to like get the job that they have?*

Alice *A lot of people when you ask them* [about getting a job]*, they're like, oh it's just luck. And it's like, well, what luck did you get?*

Anna *And what kind of things did they study? And when did they make the decision that that was something they wanted to specialise in*? (AL-A group, delayed post-session interview)

There was a clear dominant interest amongst the students in both pre-session and delayed post-session interviews about the scientists themselves and science careers, although this interest revealed a drop in frequency during and immediately after the sessions relative to other topics. The data suggest that this interest in the scientist was pre-existing, long-lasting and personal as opposed to a short-term situational interest, as might be represented by the questions about science information and science process during the session and immediately afterwards (see section 3.4.2 on interest development). Students attempted to prepare for, and reflect on and understand, their experiences by thinking about the person behind the science. Shorter-term interests in science concepts, social and ethical issues and scientific processes did not seem to last beyond the immediate experience of meeting a scientist. For example, proportions of questions asked by students about the scientific process immediately after the session was 30%, which decreased to 9% of questions in the delayed post-session interviews.

The change in composition of question topics during the session compared to those before and after the session may indicate a novelty effect – questions were asked about different topics in a new situation. Alternatively, students may have been asking more questions around the scientific content because of the specimens, equipment and other media presented during the session. The proportions of question topics from the session itself are useful to consider in terms of the practical implications of the research – how sessions could be guided and developed in the future, returned to in Chapter 8. Rather than using assumptions from teachers and education staff about what might be interesting and relevant to students, questions identify areas of student interest coming from the students' themselves which could be used in future programming (as recommended by Baram-Tsabari *et al.*, 2009).

The dominance of student questions two months after the museum visit on the scientist and on science careers is interesting when considered alongside other impacts in terms of how students identify with scientists as a result of meeting them face-to-face. In section 6.4, the impacts were discussed in terms of students' identifying with scientists around careers in science, often with students making explicit links between their own ideas and plans and those of the scientists. It is likely, therefore, that some of the questions students posed about science careers and the life of a scientist were helping them to understand and develop their perceptions of what being a scientist would be like, as they aligned themselves with the scientists they met and considered their own career paths. This process may, therefore, have led to longer-term impacts on students' plans for science careers and study in the future.

6.5.3 Comparison of trends in questioning

Comparison of the questions asked by Nature Live visitors and A-level students by topic reveals some interesting differences between the two groups. The most noticeable difference was that the students asked a higher proportion of personal questions about the scientist. The personal category of questions has the highest proportion of questions in three out of the four data collection points for students, whereas for visitors, personal questions were the most frequent in the delayed post-session interviews only, along with questions on science information. For visitors, the highest proportion of questions asked focused on science content and information.

During sessions, both groups asked the highest proportion of questions about science information compared to the other question topics. Compared to other data collection points, the most questions about science information were asked within the sessions. These trends indicate that the content and set-up of the sessions encourages science content and information questions over others.

Comparing the trends in question topics of both groups highlights that these audiences were different in a number of ways. These differences must be considered when developing future meet-the-scientist sessions. There may be more differences between the student and Nature Live visitor audience than might be expected as indicated by the questions posed by visitors and students before the session. More could be done to tailor these meet-the-scientist sessions to the needs of each group, to maximise the impacts of sessions and to foster interest development in each group. Findings also highlight the complexity of impacts on visitors and students, in terms of areas of interest and the development of new or existing interests.

6.6 Summary

This chapter has discussed how meeting scientists face-to-face had an impact on how visitors and students identified with scientists and science. The interactions with scientists had positive impacts on both groups. The Nature Live visitors were able to make connections to the scientists in terms of their personal lives, hobbies and places they had visited. Students identified links to the scientists they met in terms of their own career plans, understanding of jobs in science and imagining themselves in roles similar to that of the scientist. There was evidence in both interview responses and field-notes of some visitors positioning themselves more closely to the scientists in relation to the rest of the audience.

Data from visitor and student questions indicate that both groups used questions as a way of identifying with scientists. Both groups generated a high proportion of questions about the scientist themselves, demonstrating a desire to know more about the scientists and their personal career history. Adult visitors developed an interest in the scientists themselves as a result of the sessions; students were already interested in the people behind the science. The questions of the participants support other findings reported in this chapter about how meeting scientists has an impact on visitors' and students' ability to identify with scientists.

Identifying with scientists is important in the development of science identities, seeing others who engage in science as 'like me' and developing into a science 'kind of person' (Gee, 2000; Holland *et al.*, 1998). This chapter has described incidences of visitors and students developing their own science identities through question-asking and making comparisons and connections to the scientists. This type of identity work has been described previously in museums (Rounds, 2006) and in relation to the development of science identities at school (Tan & Barton, 2008); the current research combines both strands of work. The findings of the current study are important as they indicate that participants are becoming more interested in, and connected to, the scientists and their science and, therefore, are more likely to seek out similar experiences, which contributes to the development of scientific literacy and engagement. Question-asking has not been studied in this way previously, to reveal such promising findings in relation to identification with scientists and science.

The analysis of visitor and student questions in this study goes beyond previous research into interest in science. Questions are seen as an indicator of interest in addition to and not the result of prompting in the form of an interview where a participant is asked directly to self-report areas they find interesting. The use of visitor and student questions offers a potentially more valid measure of interest in a certain topic; in generating questions, participants are expressing the desire to know more about the subject and, therefore, going beyond a positive reflection on the topic, such as 'it was interesting'. Questions can, therefore, be used in the triangulation of data; trends identified in terms of becoming more interested in the scientists and their individual stories can be compared with findings drawn from other interview data. For example, participants also mentioned that they valued meeting the scientist as a unique experience, they formed links to the scientist on a personal level and also recalled information and new understanding about the scientists' area of specialism. The fact that these themes support one another adds strength to the conclusions around visitors and students identifying more closely with scientists and becoming more interested in them personally.

Despite arguing that asking questions is an indicator of interest and represents a desire to find out more information on a given topic, I am not claiming that asking a question in these contexts of the interviews or Nature Live sessions means that participants will seek out the answer in another context. Questions are used to represent a sparking of a situational interest and that the visitor or student is engaged with the science and scientist momentarily. This distinction is important when considering Nature Live or behind-the-scenes tours as part of a wider network of learning experiences; asking a question in one context does not necessarily translate to another. Researchers looking at questions asked on an online Ask-A-Scientist website are also cautious in their interpretation of their results – asking a question on the website does not translate to asking it in the classroom, or seeking the answer from other sources (Baram-Tsabari *et al.*, 2010). If the interests sparked when meeting scientists are to be supported and sustained, opportunities for continuity between other learning contexts would be beneficial so that individuals could engage in further related activities.

Through seeing scientists and science as connected to their everyday lives and future plans, and in developing interests in the people behind the science, visitors and students may be encouraged to engage with science and scientists in the future. These findings suggest that opportunities such as Nature Live may go some way in promoting scientific literacy and engagement with science through enabling visitors and students to identify with scientists. This chapter has detailed how meeting scientists has an impact on visitors and students in terms of identification with scientists and the development of science identities, but these findings may or may not lead to longer-term impacts on scientific literacy and engagement. The final data chapter, therefore, explores the long-term and further broad range of impacts of meeting scientists, discussing evidence of continued engagement with science and the potential for lasting impacts beyond the study duration.

Chapter 7: Further engagement and impact longevity

7.1 Introduction

This study contributes to knowledge of the duration of the impacts of public engagement activities beyond the immediate experience. Chapter 5 highlighted the complex impacts meeting scientists had on visitors' and students' perceptions of and ideas about scientists; Chapter 6 discussed how visitors and students identified personally with scientists and internalised their experiences in a way that was meaningful to them. This chapter discusses evidence of longer lasting impacts of meeting scientists – particularly impacts evident in delayed post-session interviews up to two months after the initial event. The data presented in this chapter illustrate the further breadth of impacts of meeting scientists on individuals, particularly in relation to science literacy in the form of learning, and engagement in terms of indicators of future behaviour and interest development. Data here are used to address the question in the overarching study focus 'to what extent do impacts last beyond the immediate experience?' Interest development theories are used to explore these data on sustained engagement, to establish whether long-term interests are triggered and supported as a result of meeting scientists and, therefore, whether further engagement with science is likely to be encouraged (Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006; Krapp, 2002).

To make relatively confident conclusions about the impacts of museum experiences such as meeting scientists on science engagement and literacy, it must be established whether or not impacts last over time because without longevity, any broad or sustained change in science engagement and literacy is unlikely. Despite the need for study into the longevity of impacts, there are limitations and challenges in studying longer-term impacts. Participants were aware that they would be interviewed two months after the visit – this was made clear in the research information sheet and in the oral briefing – and this may have influenced their behaviour. A discussion of these issues was covered in section 4.6.

Visitors and students exhibited evidence of learning over time and continued engaging with relevant scientific topics following their museum visit, from 'everyday' examples such as talking about the scientist with friends and family to specific activities such as buying a book on the scientific topic of the session or researching a related question online. Some students' responses suggested that meeting a scientist may have had a lasting impact on their career options and decisions. These findings are important, alongside the impacts reported in the previous two chapters regarding identification of and with scientists, as they provide a sense of broader impacts as well as longevity and endurance of impacts.

The presence of impacts on identification of and with scientists in delayed post-session responses suggests that they are sustained over time. Some of the delayed post-session responses were used as examples and illustrations in the previous chapters. What follows is a discussion of other lasting impacts of the experience adding to those discussed above, including learning and participating in activities relevant to the session. This chapter makes the case, therefore, that the impacts identified in this research lasted at least two months after the visit and were likely to have lasted longer.

7.2 Learning impacts

Visitors and students attending Nature Live sessions and A-level days learned about science as part of their visit. This learning is evident in delayed post-session interviews two months after the interaction with the scientist. Some visitors and students were expecting and hoping to learn as a result of the session, but for others learning was an unexpected outcome. Visitor and student learning was revealed by the ability to recall specific facts. These facts had often surprised the visitor or student in some way, contrasting with what they had previously thought before the visit. In Chapter 2, a definition of learning used in this research was posed: learning can be seen as a change in, or strengthening of, a person's attitudes, interests, knowledge, perceptions, understanding and behaviours, compared to before the learning experience. Chapters 5 and 6 described evidence of learning in terms of changes in perceptions, attitudes and interests, whereas in this chapter evidence for learning in terms of knowledge, understanding and behaviours is discussed.

7.2.1 Meeting scientists as learning experiences

Visitors' motivations for attending Nature Live events varied. Motivations are important as they drive behaviour and are the intrinsic factors encouraging future engagement linked to interest and learning (Hidi & Harackiewicz, 2000; Renninger *et al.*, 1992). Motivations for attending a Nature Live session, as cited by visitors during pre-session interviews, are presented in Table 13. The most cited reason for choosing to attend an event was because the subject sounded interesting (29/81 visitors). The next most frequently cited motivation – and particularly relevant to this section of the findings – was to learn something (21 visitors). Visitors were relatively unspecific in terms of what they wanted to learn – they did not usually come with a predetermined agenda in mind but gave reasons such as 'To pick up something new' or to 'Find out something I didn't know before'. Such answers indicate that the topic itself and learning something new were in the minds of the visitors attending the events and, therefore, they were expecting to develop conceptual knowledge by attending the session.

Table 13. Reasons cited by visitors for attending a Nature Live event (n = 81).

Motivation for attending Nature Live session	Frequency of visitors (pre-session interviews)*
Interested in topic	29
To learn	21
To meet a scientist	12
Event sounded interesting	9
Attended previous events	9
Wanted to see Studio	6
Experience for their children	3
It is a new experience	1
Was on at a convenient time	1
Wanted to handle specimens	1
TOTAL	**92**

*Some visitors cited more than one reason

Students attended the Museum as part of a visit planned by their teachers as part of their A-level biology course. The question about motivations for attending the session, therefore, was not as salient for the students as it was for the adult visitors. The students were, however, asked what they were hoping to get out of the session. Although not the same as motivations for coming, responses to this question are indicators of what could have appealed to the students about the sessions they were due to attend. The students' responses are given in Table 14. Learning something new was the most frequently cited hope, followed by the opportunity to see some of the Museum's specimens and to see the scientists at work.

Table 14. Hopes for the A-level day cited by students (n = 38).

Hopes for A-level day	Frequency of students (pre-session interviews)*
Learning something new	14
Seeing specimens	5
Meeting the scientists	4
Fun experience	4
To develop a new or renewed interest	3
TOTAL	**30**

* Not all students mentioned hopes for the session

Not surprisingly, perhaps, A-level students seemed to be more driven by the learning opportunities of the session whereas Nature Live visitors seemed to be driven by their interest in the subject. Referring back to the questions participants generated to ask scientists (section 6.5), Nature Live visitors had more questions about the science content than about other topics, in the pre-session interviews. This trend accords with the cited motivations for attending sessions in that the topic sounded interesting and that they wanted to learn about it.

Other research has also shown that visitors identify museums as places to learn and that expectations around a visit and activities are likely to include learning something (Hein, 1998). In an earlier study, the motivations of visitors attending a museum, aquarium or art gallery were gathered using a questionnaire (Packer & Ballantyne, 2002). Visitors to museums were more likely to expect to learn something than visitors to other environments, reflecting the high frequency of visitors expecting to learn through meeting the scientist at the Museum in the current study.

7.2.2 Specific learning

Visitors to Nature Live events learned specific facts about the scientific content of the session and many recalled these facts in interviews more than two months later. Specific facts are defined here as a sentence or two which demonstrates new knowledge about the scientific topic of the session. Often these facts were things that surprised visitors, or which stemmed from questions they had before the session. Forty-one visitors recalled specific facts after the session, with 24 of those visitors recalling specific facts in the delayed post-session interview two months later. Additionally, 27 visitors mentioned having learned something in an unspecific or broad way in the post-session interviews; 20 mentioned general learning in the delayed post-session interviews. General learning comments included those where visitors mentioned that they had learned about the subject, or developed their understanding or broader knowledge, but did not recall any individual facts they had learned during the session, as in the specific fact learning category. Examples of specific fact learning are given below, and include one from a key individual from Chapter 5, James N:

Moriarty *There was one thing, I didn't know that platypus in the south of Australia are bigger than the ones in the north!* (NL-Q, post-session interview)

Elvis *So you know how the clown fish is once male and then it goes to female. That was quite interesting from an informative point of view.* (NL-Za, post-session interview)

James N *I think the interesting thing is what you are allowed to have in your foodstuffs. So in peanut butter you're allowed 30 insect pieces*! (NL-Zx, post-session interview)

Katie *And the other thing we really remember was the fact that mammoth hair is not orange!* (NL-Zg, delayed post-session interview)

Visitors remembered this information and were often amused by their new facts as they contradicted prior ideas or were in some way unexpected; this is useful information for Museum staff developing the Nature Live sessions and for the scientists themselves. As the majority of visitors attend due to an interest in the subject or to learn something new, including key and potentially surprising facts such as those mentioned above is likely to satisfy the interests of the audience and be memorable to the visitors after their visit. Further practical implications for museum professionals are discussed in section 8.5.2. Including surprising facts or anecdotes may be more difficult than it sounds, however, due to the varying backgrounds of the visitors and different levels of knowledge and experience in science. Perhaps personal anecdotes or surprising stories relating to the scientist are, therefore, potentially useful to include in sessions as members of the audience are unlikely to have heard about these before unless they know the scientist already, and personal stories tie into some of the other impacts including portraying scientists as approachable and friendly.

Visitors learned facts as a result of their interactions with scientists which contradicted what they had previously thought due to experience with other sources of science information.

This suggests a didactic approach is used in the Nature Live sessions, in which scientists 'taught' audiences information. Such an approach would replicate science communication initiatives which are based on the transmission model, whereby audiences are seen as empty vessels to be filled with the knowledge from experts in the field. In thinking about engagement approaches on a spectrum, a didactic approach, in terms of a passive audience, may be at one end. At the other end would be an interactive and dialogic approach which empowers audiences to engage with science themselves, encouraging them to be interested and confident with science and scientists, to identify the relevance and importance of science in their own lives and to have the skills to interrogate the information they encounter. This latter approach to science engagement reflects the changes put forward in the House of Lords report *Science and Society* (UK House of Lords Select Committee on Science and Technology, 2000) and in publications (such as Wilsdon & Willis, 2004) which call for a move from didactic science communication towards engaging and involving different publics in science in a more active and influential way. Despite these movements, public engagement with science often manifests itself as the provision of information to the public rather than as a forum for public *and* science communities to debate issues (Besley & Nisbet, 2013).

Other impacts discussed above suggest that visitors and students are in fact evaluating the scientist as a reliable source of information, which is a positive outcome in terms of promoting scientific literacy and engagement. Visitors described scientists as experts and as being knowledgeable in their field (section 5.7) and saw the opportunity to meet a scientist as an authentic and exclusive experience (section 5.7.3). Considered alongside other impacts of the experience, therefore, visitors appeared to recognise scientists as experts in the area, understand more about the rigorous process of scientific research and specialism within science, and, as a result, value the information provided by the scientist as more reliable in comparison to other sources.

A balance may be required in developing discussion events such as Nature Live and in recognising what Nature Live events can and should be. Audiences might benefit from being able to steer and contribute to the session direction, pausing on, or skipping over content they find more or less interesting or engaging. If the limits of scientists' areas of expertise were made explicit, the audience might be enabled to evaluate the information and make judgements on its reliability. Expertise and authority as well as interaction with a friendly person may be required in discussion events such as Nature Live in order to promote impacts on visitors. With this balance in mind, it is suggested that the impacts of the session are likely to promote scientific literacy and engagement. Sessions may do this by increasing interest and learning in science along with the confidence and awareness to evaluate sources of scientific information in the future, engage in conversations about science and make informed decisions based on the available evidence. Scientists could do more to invite other sources of expertise into the discussion (Blok *et al.*, 2008; Irwin & Wynne, 1996; Wynne, 1992), asking visitors and students to share their experiences with the topic, or encouraging alternative ideas, to present different perspectives and engage visitors and students in a more active way.

Students also mentioned learning as one of the main benefits of the session. However, there were fewer mentions of learning from the A-level students compared to adults visiting Nature Live events. Five students mentioned specific learning outcomes although they did not contrast them to prior ideas or conceptions as the adults did. For example:

Hermione *She was talking about all the, like, different life cycles and different worms. And she was talking about how, what different animals they live in and how every animal on Earth has a worm for them, that lives in it. And she even talked about some of the animals that we eat, what worms they have, like fish and stuff, salmon and beef, pork has a few, and lamb as well!* (AL-C group, delayed post-session interview)

Two students mentioned general learning outcomes in the delayed post-session interviews. For example, the following student explains how the session helped consolidate some of the learning he had undertaken at school:

Julius *I suppose consolidating […] the knowledge that we knew before and made sure that we actually knew it, which was good.* (AL-I group, delayed post-session interview)

The presence of content learning amongst the breadth of impacts of meeting scientists supports findings from previous studies into learning outside the classroom. School pupils (aged 11-18) attending a university science laboratory in the US articulated four groups of impacts of their experience of which improving science content knowledge was one (Luehmann, 2009).

Learning science content knowledge as a result of meeting scientists also supports the findings of the literature on communities of practice which describes how novice members of a group learn by interaction with more experienced and knowledgeable individuals (Lave & Wenger, 1991; Wenger, 1999). In the current study, visitors and students acted as novice members of the community of science, interacting on the periphery of the science community by listening to and interacting with the scientist. As a result, these novice members were able to learn something from a more knowledgeable member of the group, experience the language used in the community and were given the opportunity to participate themselves by asking questions or making comments. Although the visitors were unlikely to continue to become scientists, they were participating in a community where they may become individuals interested in science, learning and interacting with someone who is more actively interested in science than themselves currently.

Following the community of practice model, further contact with scientists or other more knowledgeable individuals in the community of science could lead to increasing understanding and the participation of the more novice individual with science – increased scientific literacy and engagement. Examples of how this participation in the community of practice of science could continue for the particular participants involved here include returning to a Nature Live, attending another discussion event, taking part in another type of museum activity in the future, engaging in conversations with family or friends who might work in science, or having contact with other scientists through school visits, higher education or work. Such continued engagement with science may lead to increased science capital (Archer *et al.*, 2012b; Bourdieu, 1977), which would reinforce the likelihood of further engagement with science.

7.3 Further engagement

It is to be hoped that meeting the scientist at either Nature Live events or A-level behind-the-scenes days is not a one-off for the visitors and students interviewed, but that it is part of an on-going series of science engagement activities. Comments about any other engagement with science, therefore, were analysed from post-session and delayed post-session interviews, to collate evidence that participants had subsequently engaged in similar activities, or had the intention to do so. Continued engagement and intentions to do so in the future are key targets of this research which aims to explore how meeting scientists could increase visitors' and students' scientific literacy, confidence and interest to engage with science in the future.

The most popular type of continued engagement mentioned by the participants was an intention to return to the Museum and attend another Nature Live event: 62 out of 81 visitors mentioned specifically that they would return and see another session. No participants said that they would not return, although one participant did say that the session had made him less likely to rush back to another one because he had wanted more in-depth and specific information from the session than he had experienced. During data collection, I saw three participants at subsequent events, illustrating continued engagement with the Nature Live programme. One visitor mentioned that she had become a Member of the Museum[13] following the Nature Live event and that the session had been part of her decision to become a Member.

Realistically, however, not all participants lived near the Museum and would not be able to return frequently even if they had wished to do so, therefore other examples of engaging with the scientific content of the session were identified. These examples of engagement took the form of conversations with family and friends about the session and the scientists at the Museum and more specific research into the scientific content of the session.

7.3.1 Everyday engagement

In delayed post-session interviews, many visitors spoke about how the session, the scientist, or the scientific topic had cropped up in their everyday lives following their visit to the Museum. Such occurrences were in conversations with friends, family or colleagues – 38 visitors mentioned that they had told other people about the session and meeting the scientist. For example, Laurie, an example case from Chapter 5, commented in her delayed post-session interview that: '*I shared it with some colleagues at work'.* Visitors mentioned that the session had cropped up in conversations about what they had done at the weekend, during the holidays, or when making recommendations for what others might do on a visit to London. For other visitors, speaking about the session was a chance to pass on some of the specific facts they had learned, as mentioned above in section 7.2.2:

Katie *Yeah, we chatted to family and stuff about what we'd seen, and to my mother-in-law and everything, and yeah, it was interesting. And I think we spoke to a few people at work and stuff about it. We were telling everyone – mammoth hair is not orange! So that has been spread!* (NL-Zg, delayed post-session interview)

[13] Membership to the Museum can be purchased by paying a subscription fee, for which Members receive free entry to special exhibitions and Members' events, discounts in museum shops and free museum magazines, amongst other benefits.

Conversations with family and friends represent a way in which science may connect into the everyday lives and worlds of students and visitors. Previous work on science attitudes and engagement of students found that when the worlds of family and peers overlapped and supported the world of science education, students were more likely to engage with science and have positive attitudes towards it (Costa, 1995; Zimmerman & Bell, 2012). This previous research suggests that evidence of participants speaking about their experiences meeting the scientist with family and friends is significant in terms of their everyday world supporting the development of positive attitudes towards, and engagement with, science.

One visitor mentioned in the delayed post-session interview that he had not spoken about the session with others, but had thought about it more himself. Another visitor mentioned how she intended to speak to colleagues about the scientist she met who researches bees when she was next in work, but had not yet done so.

Fourteen visitors stated in delayed post-session interviews that attending the session and meeting the scientist had made them more aware of, and interested in, other things they encountered in their lives. One couple spoke about how attending a session on fossils made them more interested in watching a television programme about the same topic a few weeks later. Amelia, an example case individual from Chapter 5, described how a session she saw about UK biodiversity had an impact on how she engaged with her own backyard:

Amelia *I mean the whole thing it was just an eye-opener really. I think I said at the time, it certainly made me think more. I mean we haven't got a garden at the moment we've just got a backyard with pots in. But even with, even with those, it's made me more aware of the small amount of wildlife and things that we* ***have*** *got in the garden.* (NL-Zk, delayed post-session interview)

Students also mentioned how the session had had an impact on them up to two months after the visit. Similarly to adult visitors to Nature Live, the most common way in which students continued engaging with the science they saw at the Museum and the experiences they had meeting a scientist was to speak about it with family and friends. Thirteen students (out of 38) said that they had spoken about the visit to someone else. For example, the following student described how she told her mother about what she had learned during a session about chocolate and how more expensive chocolate usually contains the better quality ingredients:

Lilly *I went home and I was like, 'Mum we're not buying normal chocolate anymore'!*

Interviewer *Yeah, and what did she say?*

Lilly *She was like, 'Why?', and I told her, and I told her everything - I sat down for, like, half an hour and told her everything. And she was like, 'OK, we'll buy expensive chocolate.'* (AL-C group, delayed post-session interview)

Five students spoke about how the session had changed their behaviour in some way. Continuing the example from above, Lilly went on to give an example of how the session had changed her eating habits:

Interviewer *And have you been eating the more expensive chocolate?*

Lilly *Yeah, I actually have, I bought one with, like, 70% cocoa in it.* (AL-C group, delayed post-session interview)

Another student explained how a session on parasitic worms had made her feel differently about eating sushi, leading to a change in her behaviour:

Interviewer *Have you eaten sushi since?*

Safiya *No!*

Interviewer *Is that because of the tapeworms, or just because you don't really like it and don't have it?*

Safiya *Tapeworms!* (AL-C group, delayed post-session interview)

In contrast, one student mentioned that the session had not changed her behaviour – she still bought cheap chocolate despite learning about the poor quality ingredients.

In terms of furthering engagement with science, one student mentioned how her visit to the Museum inspired her to return, this time bringing her family with her:

Interviewer *Yeah, and did you tell anyone about it, tell your family or any other friends that didn't go to the Museum?*

Apple *Actually I did and my family went on a trip back to the Museum.*

Interviewer *Oh really – as a result of what you had said about the Museum?*

Apple *Yep.* (AL-G group, delayed post-session interview)

Betty Boop, the example case student from Chapter 5, also said that the session had an impact on her attitudes towards further visits to museums:

Betty Boop *And also, I've noticed other museums around, because of that museum I want to go to other museums*. (AL-C group, delayed post-session interview)

Another student described how his experience at the Museum fitted alongside other experiences, creating a cumulative effect on his attitudes to science:

Newton *I mean the going to the Museum behind-the-scenes that was an important part. But it's also everything else, sort of TV documentaries and things like that. And also that was what sort of, like, pushed me over the edge, like this* [science] *can actually be fun and there are some interesting people that do it.* (AL-B group, delayed post-session interview)

Visitors and students continued their engagement with science beyond the immediate museum experience: by seeing connections between the session and their everyday lives; increasing awareness and appreciation of the topics of the session; and participating in conversations and activities relating to the scientist, the museum and the session. Such continued engagement may encourage the visitor to see the relevance of the science and the scientist to their everyday lives, develop any interest sparked from the session and continue with finding out about the science content. Continued engagement over time and within the home environment supports the development of interests within science areas, promoting further engagement (Zimmerman & Bell, 2012). Where individuals can see congruence between science, their home lives and their friends and family, they are more likely to develop science identities and engage in science in the future (Costa, 1995; Kozoll & Osborne, 2004).

In order for visitors to develop their own science identity, it is important that science is seen as relevant and personally interesting (Kozoll & Osborne, 2004). Studies into the development of science cafés for young people have stressed the importance of making science engaging and relevant to young people's everyday lives by providing opportunities to interact with scientists in an accessible way (Hall, Foutz, & Mayhew, 2012; Mayhew & Hall, 2012). Earlier research supports the influence of personal value on engagement with science: students seeing scientific content as more personally valuable, enjoyable, interesting and relevant are more likely to engage in science compared with other students (Ainley & Ainley, 2011b). The current study, therefore, indicates how museum experiences could encourage visitors and students to see science as relevant and interesting, encouraging continued engagement.

7.3.2 Follow-up research by participants

Some participants reported that they had carried out specific follow-up research relating to the session after their visit. This type of activity might include looking up their questions online, searching for more information, or buying a relevant book. Such behaviour is important as it indicates a sustained interest over time in the particular topic, suggesting interest development had been triggered as part of the experience of meeting a scientist. Self-directed research could indicate that the interest had been sustained and had developed into a personal interest from a short-term situational interest (Hidi & Renninger, 2006). Post-session interviews gave indications that a short-term interest had been triggered: eight participants expressed an intention to carry out some sort of follow-up research when they got home. For example:

Charles *I think, yeah I want to go back and read up on mammoths now.* (NL-Zg, post-session interview)

In delayed post-session interviews, visitors were asked if they had carried out any follow-up research such as looking up any related information online. Thirteen visitors reported that they had researched something relating to the session, online or in books, following meeting the scientist. Five visitors, including Charles from above, mentioned in delayed post-session interviews, that they would still like to carry out some sort of follow-up research, despite not having done so thus far. Finally, of those remaining who had not carried out specific follow-up research into relevant topics, twenty-one visitors gave reasons for not having done so, including not having enough time or forgetting to do so.

Of those visitors carrying out some sort of follow-up research, the majority had briefly browsed relevant websites, including the Museum website or Wikipedia, finding out the answer to a specific question, for example 'What is the difference between plants and animals?' or searching about the subject, for example mammoths. Here are two examples of visitors speaking about the research they conducted:

Mildred *Yeah, I did do. I went on the natural history website, but I also did the old favourite Wikipedia, and went on that as well*. (NL-G, delayed post-session interview)

Didier *I did look up more about what I can find about the organisms, on the internet. And it mostly directed me to the Natural History Museum website anyway, I think. And I did find a bit about the lecturer, the researcher. And then I found out that there are more* [research studies] *being done, more that was being done*. (NL-Zh, delayed post-session interview)

For one couple, however, the session was just the start of an interest in seaweeds: they reported during the delayed post-session interview having carried out some extensive follow-up research which they planned to continue. In the interview excerpts below, the couple refer to how the advice from the scientist had helped them to identify the best information to continue their interest most easily and how they planned to carry on researching the topic of seaweeds based on the scientist's guidance:

John *I have no idea how I would have found it* [the Field Studies Council website, without asking the scientist about it], *because I don't really know how to ask the questions properly. Ask them and I try to Google it and stuff like that. And it's very difficult. Because you find a lot of things if you Google it, but it gets too advanced, and I can't follow it along.* (NL-Zv, delayed post-session interview)

John *It's my birthday next month. And guess what is on the wish list! Actually it turns out that when you start looking into this one* [particular book] *it is quite expensive. But actually it turns out that the Natural History Museum, they have a production of books. And it actually turns out that some of the books* [are] *published by the Natural History Museum – and guess what is on my wish list for next month!*

Interviewer	*Oh, one of those ones?*
John	*Yeah, and there is actually a book by a guy called David Thomas, and that is from the Natural History Museum. So I am hoping to get that one. At the moment I am looking at my wife and –*
Interviewer	*Smiling sweetly?*
John	*Yeah exactly!* (NL-Zv, delayed post-session interview)
Lyn	*Well John has, and I've been, you know, trailing along and sanding through the bushes, but it's mainly John who has been interested in it afterwards. So I've been looking at the material but I haven't found it all actually. I know he's looking for some books for his birthday, and I expect to browse through them as well.* (NL-Zv, delayed post-session interview)

The case of this couple is rare and, perhaps, extreme, but it demonstrates the potential of sessions such as Nature Live for sparking long-lasting interests in visitors.

Interview responses from students also described follow-up research and engagement after the visit. Research indicates that pre- and post-visit activities are important in strengthening and increasing the impacts of school visits and out-of-school experiences (see DeWitt & Storksdieck, 2008, for a short review). For example, a study in Australia focused on two students (aged 11 and 12) as case studies from a wider sample who took part in a museum visit and relevant post-visit activities relating to the content of the science museum exhibits (Anderson *et al.*, 2000). These students indicated development of their scientific understanding of the concepts of electricity and magnetism following the delayed post-session activities, demonstrating reconstruction of their knowledge through concept maps. However, in the current study only one group of students reported that they had undertaken specific work at school to follow-up their visit. Two groups indicated that the content they had encountered as part of their museum visit had cropped up in their classwork, but that they had not been given any specific work to follow on from their museum visit. A practical recommendation for the Natural History Museum from the current research could be to develop delayed post-session activities for the students attending the behind-the-scenes A-level days to encourage teachers to follow-up the visit and maximise its impacts.

Despite the lack of formal structured learning activities provided to follow-up the museum visit, some students did carry out research on their own initiative. Such behaviour is driven by intrinsic motivation without external reward and suggests that sustained interest development has been triggered (Hidi & Renninger, 2006). Students stated that they looked at the Museum website for relevant books and information, read up more about principles they had encountered on the day that they found complex such as carbon dating, and about the research they had heard about:

Interviewer *Yeah, and did you look up anything about the topics that you heard about?*

Walrus *Erm, I did, I'm not sure about anyone else.*

Interviewer *Yeah, what did you look up?*

Walrus *Erm, I went home and just looked about the dinosaur research.* (AL-D group, delayed post-session interview)

Evidence of any continued engagement is important as it represents an adoption of elements of the session and the experience of meeting the scientist into the visitors' everyday lives. Talking about the Museum, looking up the scientist on a website or watching them on television programmes extends the experience. Taking part in these science-related activities supports the development of science affinity identity, participating in the practices of science and developing shared interests with other science 'kind of people' (Gee, 2000). These delayed post-session activities may then facilitate continued learning about the scientist, their work and the science content, reinforcing interest so that a maintained, personal level of engagement may develop (Hidi & Renninger, 2006; Krapp, 2002). It is through reinforcing experiences such as these that the impacts of meeting scientists are sustained significantly beyond the visit itself.

Many studies in museum education have been limited to studying the immediate or expected impacts on engagement with science. This study, through the inclusion of a delayed post-session interview, enabled data on engagement after the visit to be collected. The evidence from the delayed post-session interview responses presented above suggests that some impacts relating to engagement and interest last at least two months.

7.3.3 Potential long-term career impacts

One way in which meeting scientists may have had potential long-term impacts on engagement is through influencing attitudes towards science careers and understanding of what jobs science might lead to. Students' interview responses indicated that meeting scientists had an impact on their understanding and awareness of as well as their attitudes towards science careers and, therefore, their plans for pursuing science in the future in terms of work or study.

i) Perceptions of science careers

Findings reported above in Chapter 5 demonstrated a duality in perceptions about scientists. Chapter 6 indicated how students formed links to the scientist in terms of identifying with their career ideas and work. Developing multiple views of scientists and their work, grounded in reality, may be helpful for students to see themselves in science, therefore, and make informed career and study choices. Meeting scientists may make a useful contribution to shaping more complex perceptions and understanding around scientists and their work, leading to increased scientific literacy and the potential for long-term engagement in science careers. For example, research involving case studies of UK students making their science career choices concluded that those students who were aware of the breadth of science careers, who had an open mind about science and who had a realistic picture of scientists (that is, being less likely to stereotype scientists), were more likely to choose science as an option for themselves (Cleaves, 2005).

All students were studying A-level biology and were, therefore, more likely to be considering careers in science than the average adult Nature Live audience member. Meeting a scientist had an impact on students' understanding and awareness of science work. Students not only noticed new characteristics about scientists, or had old perceptions challenged, but some also developed a new insight into the job and career of a scientist as a result of meeting the researchers. These new perceptions and insights may have triggered longer-term impacts in the form of intention to participate in further study or careers in science.

Students' interview responses indicated a number of different ways in which the sessions had an impact on their understanding and awareness of scientific careers. Firstly, students became more aware of the jobs of individual scientists and felt they had a better grasp of what a typical day in the life of a scientist might involve. As a result, they developed a more advanced understanding of specific procedures or tasks that the scientists might carry out. Eighteen students made comments in post-session and delayed post-session interviews demonstrating a development of understanding of the day-to-day work of scientists. For example, the three students below described how they were shown specific processes that the scientists might carry out themselves. Caroline, the third student quoted below, began to place herself in the role of the scientist, exploring how she would feel taking part in these tasks and considering whether she believed she would be able to fulfil the role of a scientist as described to her:

Sampson	*I think I understand, the processes have been explained a lot more, the whole extraction of DNA and those investigations that they do, that's something I know now that I didn't know before.* (AL-F group, post-session interview)
Aurelia	*He talked a little about how fossils were, like, carbon dated or something, like, he told us about how you can find out the age of them. And he was talking – oh yeah, he was talking about global warming and they are trying to figure out if this one period of extreme heat, like, way back when, and then it went back down after, like, a couple thousand years or something. And they were trying to determine, like, what effects this warming had, and how can we use this information to tell us what's happening to us.* (AL-G group, delayed post-session interview)
Caroline	*The only minute differences in, like, the different samples they had, but I would never be able to pick out the relationship between them, like, there you have the juvenile part and the adult part. I'd never be able to make that connection, you're looking for such fine details that if, like, if, I don't know if you are not looking at precisely the right thing or if you get it, you get your description of it slightly wrong, you could, you make an absolutely huge mistake that could blow a hole in your theory.* (AL-H group, post-session interview)

Caroline also mentioned that the session gave her an insight into what the working environment of a scientist might look like:

Caroline	[It was] *an insight into a working lab with scientists because you know we walked in there and it was completely cluttered, papers and equipment everywhere, it felt like it's been used quite recently.* (AL-H group, delayed post-session interview)

Envisaging the working processes and environment of a scientist is important because if students are to imagine themselves taking part in scientific activities then being able to picture their surroundings could be helpful. Amongst other factors identified to contributing to positive student attitudes towards science careers include students being able to see themselves in the surroundings of a scientist and understanding the work that a scientist is likely to carry out (Cleaves, 2005). These factors enable students to see science as ‘for me’, rather than as something not personally interesting, relevant or achievable.

Four students made comparisons between the scientists they have seen elsewhere and the scientists they met at the Museum, in terms of what their job entails. For example:

April	*I think I feel a bit more, like, scientists have a kind of interesting job, compared to scientists I've seen around school. Yeah and seeing a scientist in that environment made me think, maybe they don’t only just sit down in a lab, they go out and do stuff as well.* (AL- H group, delayed post-session interview)

April, above, was pleasantly surprised with what she saw being a scientist could involve, compared to other scientists she has ‘seen around school’ – she may have been referring to laboratory technicians here, visiting scientists or, perhaps, her teachers. In contrast, Eddie was slightly disappointed with what he saw of science careers at the Museum, compared to those portrayed on television:

Eddie	*I was personally a little bit disappointed with, erm, what scientists do. Compared to like what they do on television.*
Interviewer	*Yeah, so what kind of, did it look less exciting than…*
Eddie	*Less exciting than something like CSI for example.* (AL-H group, delayed post-session interview)

Eddie’s responses indicate issues for public engagement with science – initiatives are competing with media representations of scientists and their work, be they positive or negative. Public engagement with researchers, therefore, has a role in portraying an image of science and scientists based on reality. Such an approach to public engagement will promote scientific literacy, based on accurate and real science, and support science engagement whilst managing realistic expectations.

Four students developed a better understanding and appreciation of the broad remit of the Museum's scientific research and the work of the scientists there through their experiences on the day. For example:

Alice *Because they're such different ends of work, because she works in like this little room, little library room, and he sort of goes to, like, people.*

Ruby *He works with the police and stuff.* (AL-A group, delayed post-session interview)

Caroline *Because her just now, I don't know, she's just in charge of the archives, going through, comparing it. Whereas the guy this morning is actively going out there, collecting samples, identifying them, bringing it all back here and going through it properly. Which is a lot more hands-on than running it through an archive.* (AL-H group, post-session interview)

Similar findings were reached following research in the US into the impacts of interactions with scientists during a week-long nanotechnology programme on students aged 12-13 and 15-16 (Painter *et al.*, 2006). Following the programme, students saw that scientists had a diversity of roles in many different places and in various subjects. The students above indicate broad perspectives as a result of meeting Museum scientists, and made comparisons between aspects of science work they feel might be more positive ('actively going out there') and some more disparaging aspects of scientific work ('just in charge of the archives').

The experience of meeting scientists not only had an impact on student understanding of the careers of Museum scientists but also provided an insight into science careers more widely. Thirteen students, including example case student Betty Boop, developed an increased awareness of the breadth of options available in science after studying for science qualifications:

Ruby *That you don't have to just work in a lab environment, you know it's not. Because his job was so, it was using like everyday life. Just that you can combine it, combine biology with so many different careers, you can use it for a lot more fields than I thought you can before.* (AL-A group, delayed post-session interview)

Betty Boop *Yeah, because like as Mr [X] says, when you do science there's like, people stereotype you, to do like a certain job like a doctor or something else, there's not, they don't, they don't make you realise that there's a lot more that you can do than just being a doctor*.(AL-C group, post-session interview)

In terms of students becoming more aware of the breadth of science careers, some became aware of new jobs they did not know existed, as a result of meeting the scientists:

Anna *Yeah, because I didn't really know that that was something that you could do, you know it wasn't really something that I knew much about so…*

Interviewer *Forensic entomology?*

Anna *Yeah!*

Alice *Did you think it was like a made up thing that they did on CSI?*

Ruby *Yeah, like CSI, Grissom when he uses the animals to solve the case.* [laughing] (AL-A group, delayed post-session interview)

An example of how meeting scientists enabled students to consider careers in science in a more positive and broad light by identifying with scientists is provided by Betty Boop, the example case student from Chapter 5:

Betty Boop *Actually, it made me think that if you do science A-Levels, like, what careers you can do in the future. Because, like, obviously you could do something with chocolate or something like that, but I never thought about it. It just makes you think that you can do anything with science really.* (AL-C group, post-session interview)

The students' responses indicate that they are beginning to see the community of scientists and their research as broader and more diverse as a result of meeting the scientists during their museum experience. Such a broad view of science and science jobs may provide more potential for students to identify something they are personally interested in within the diversity of science careers and, therefore, enable more of them to identify with science as part of their own career plans.

ii) Lasting impacts on personal career plans

Interview responses from A-level students indicated that meeting scientists had a lasting impact on career plans and attitudes for at least two months. Eleven students mentioned an effect of sessions on their career plans in the delayed post-session interviews. Six of these students indicated that meeting a scientist had led them to consider a new direction or career path. For example:

Shaniqua *Yeah, because I want to do medicine, and usually the normal thing is because you're not allowed to take four straight medicine options* [on the university application form]*, you take one different. Usually people just put biomedical but I thought about putting biology down, as I'd like to learn something like that, and I've looked at universities that use the Natural History Museum, for stuff like that.* (AL-F group, delayed post-session interview)

Three students stated that their experience in the Museum had made them more aware of the breadth of options available to them personally (as opposed to generally, as discussed above) within the field of science. This newly discovered breadth of options in science was typically contrasted with the option of medicine, as in the quote from Betty Boop (AL-C group) above. Medicine was popular within the sample – 13 students were planning to study medicine at university:

Nightingale *Well I think that I found that there are lots of other types of careers in science, not just, because before I just thought of medicine.* (AL-B group, delayed post-session interview)

Two students mentioned that the session with the scientist had led them to think more positively about studying science further or pursuing a career in science. Students mentioned positive attitude change in a relatively unspecific sense, stating that science seemed more interesting and that they would now be more likely to consider continuing in a science-related field, specifically biology in this example:

Cool Cat *Same sort of thing I suppose, it's made me think more about a career in biology and that sort of area, it seems a lot more interesting. Made the subjects seem more applicable to today as well.* (AL-F group, delayed post-session interview)

These responses around impacts on career options are promising in terms of demonstrating the potential for continued engagement with science following interactions with scientists. With broader and more positive ideas around science, students may be more likely to see science as offering a career field which has the potential to be interesting, relevant and suited to them personally. Chapter 6 demonstrated how students were able to identify with the scientists personally, around the theme of science careers. These findings suggest that experiences involving meeting scientists are likely to have a positive reinforcing impact on the uptake of science careers albeit amongst students who already hold positive attitudes towards a scientific career, providing additional support for their existing ideas and attitudes. The influence of meeting scientists on attitudes to science careers has also been highlighted in previous studies which suggest that the experience provides more information for students to develop their ideas around science careers and opportunities for students to model and develop their own science identities (Luehmann, 2009; Roth *et al.*, 2009). These more developed ideas might encourage students into or away from science careers, although in the current study, the responses about students' own personal career plans in science all suggested a positive impact of meeting a scientist.

No students or adult visitors mentioned that the host had made them think about science careers in the same way that the scientists had for some participants. The lack of mention of the host in this way highlights the differences in roles of 'host' and 'scientist'. The host functioned as a link between the scientist and the audience, in terms of introducing the individual, asking questions, explaining the format of the session, providing technical assistance to the scientist in their presentation, and asking for clarifying terms. In this way the host was an accessible and friendly individual in much the same way that the scientist was. Perhaps what makes the difference, then, between individuals considering science careers and not science communication careers, is the expertise and 'special' nature of the scientist; the exclusivity of meeting a scientist and the way in which the session is set up to facilitate this feeling may have inspired consideration of science careers as an attractive and interesting option.

7.4 Interest development

The questions individuals generated to ask scientists were discussed in Chapter 6, in terms of indicating interest. Trends in the topics of questions asked were explored, in particular the 'personal' questions about the scientists and their careers were analysed to examine if and how participants were identifying with the scientists they met. In this section, interest development is returned to as an indicator of, and precursor for, continued engagement with science.

The main impacts on interest seen in this study were observed on visitors to Nature Live events. Visitors became more interested in the scientists personally, in their careers and on how they came to work at the Museum. This increased interest in the scientists themselves lasted at least two months after the visit – as seen by a rise in the proportion of questions about the scientist asked by visitors relative to the proportion of questions on other topics. The proportion of questions in the 'personal' category rose from 19% in pre-session interviews to 24% in post-session interviews and to 40% in delayed post-session interviews. This rise over time in the proportion of questions asked under the 'personal' category suggests a relative increase in interest about the scientists themselves and their own career paths. Visitors also formed new connections to the science subject as a result of the session and interests were sparked for some visitors in new areas (see section 6.2.2).

This interest development, therefore, may be attributed to the session. Simultaneously, visitors seemed to become relatively less interested in asking about science information, compared to before the session. The proportion of questions A-level students asked did not reveal the same change in delayed post-session interviews compared to pre-session interviews, suggesting that there was not a sustained change in the areas of student interest after the sessions compared to before. Interest is thus multi-dimensional – visitors and students have varying levels of interest in different interrelated topics.

A previous study into the interest development of Danish students aged 17-19 as an impact of an aquarium visit identified five situational variables which were found to trigger interest: social involvement, hands-on, surprise, novelty and knowledge acquisition (Dohn, 2011). Students were interviewed about their experiences and observed during the visit; the five variables emerged following grounded and iterative data analysis. The current study supports the findings of Dohn (2011), providing further evidence to support the five situational variables promoting interest development, see Table 15. The five variables were not used as an analytic framework in the current study due to the differences in experiences studied – Dohn focused on an aquarium visit as opposed to interactions with scientists – however the congruency between the findings indicates variables which are consistent in producing interest in out-of-school science learning contexts.

Table 15. Triggers of situational interest. Comparison of findings of the current study to variables identified as triggering situational interest as an impact of an aquarium visit (following Dohn, 2011).

Dohn's (2011) categories	Findings from the current study	References in thesis
Social involvement	Students and visitors valued the experience of meeting a scientist and the ability to ask them questions.	Accessibility and interactivity (section 5.8) Asking questions (section 6.5).
Hands-on engagement	The interactive nature of the session acted to facilitate the other variables, for example individuals could ask questions and handle specimens from the collections.	Interactivity of the session (section 5.8.2).
Surprise	Visitors and students were surprised by some of the content of the session. Participants were also surprised by the scientists they met – evidenced in changes in how they described scientists afterwards compared to what they were expecting.	Recall of new facts, often mentioning surprise (section 7.2.2) Changes in perceptions of scientists (section 5.4)
Novelty	Participants mentioned that meeting scientists was a novel experience, not something they did every day.	Exclusivity and 'special' nature of experience (section 5.7.3)
Knowledge acquisition	There is evidence of knowledge acquisition following meeting scientists in a number of areas. Knowledge development as an outcome of the session is mentioned in relatively unspecific terms and around specific facts.	Learning as an impact of meeting scientists (section 7.2).

The current research, therefore, supports the findings of Dohn (2011) in that five situational variables within visits to environments such as aquariums and museums may support interest development, and builds on Dohn's work and others on interest development in a number of ways. Firstly, an additional variable promoting interest development arose through the analysis of visitors' responses in this study: participants valued the authenticity of the experience and the scientists themselves. Although authenticity may be intertwined with other variables including novelty, surprise and knowledge acquisition, participants stressed the importance of the authenticity of the experience of meeting a real scientist. Responses indicated that visitors valued interacting with someone who had really carried out the work and could share first-hand experiences of science. I would argue, therefore, that authenticity is a sixth situational variable promoting interest development. In Dohn's study the students did not meet a practising scientific researcher as activities were led by a member of the education staff. The emergence of authenticity as a situational variable suggests the impacts that meeting a scientist specifically may have on visitors to learning environments such as museums, in contrast to other activities or interactions with other individuals.

Secondly, the current study addressed a limitation that Dohn identified in his own work – in that only situational interest could be explored as follow-up interviews were carried out within two weeks after the visit. The current study was able to provide evidence of a more sustained individual interest continuing at least two months after the visit, as a delayed post-session interview was carried out after a longer period. The current study, therefore, adds to the knowledge about longer-term interest development and maintenance over time following a museum experience.

The evidence of sustained interest development is significant in terms of longer-term continued engagement with science. Interest has been highlighted as a driving factor in motivation in learning and behaviour, something which has been discussed particularly in relation to education (Dewey, 1913; Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). Interest has also been the subject of research in museums – studies support the current research in indicating that interest may develop as a result of a visit to a museum or other out-of-school learning environment (Jarvis & Pell, 2005). Interest has also been used to explain the differences in motivations for museum visiting behaviour (Packer & Ballantyne, 2002; Rounds, 2004). Interest provides intrinsic motivation – that is, motivation to engage with activities where there are no external benefits or rewards. Intrinsic motivation is driven by curiosity and interest and is the basis for self-determined behaviour (Ryan & Deci, 2000). This type of intrinsic motivation is particularly important if the aim of public engagement activities, such as Nature Live events, is to increase science engagement such as seeking out new information, visiting museums and attending science events.

7.5 Summary

This chapter has discussed the longevity of the impacts of meeting scientists, with delayed post-session interview responses suggesting that impacts on visitors' and students' identification of and with scientists lasted at least two months after the initial visit. The study provides evidence of sustained learning outcomes from the sessions, including specific facts that visitors remembered and recalled. Interview responses revealed that some visitors continued to engage with related science after meeting the scientist, including: everyday engagement (such as conversations with family and friends); specific follow-up research such as internet searches; and, impacts on science career attitudes and options for students. New or developed areas of interest were also identified in Chapter 6, which is relevant in this chapter because of the importance of interest in motivation and engagement – a long-lasting interest in science may motivate individuals to engage further with science in the future, even in the absence of external motivations such as qualifications or payment. Data collected beyond the initial experience is particularly important when considering that this research aimed to contribute to knowledge on how scientific literacy and engagement with science can be encouraged within the adult population (section 1.1). Promoting scientific literacy and engagement requires a lasting curiosity and understanding about science, positive attitudes and awareness towards science, and sustained motivation to engage in science activities in the future.

The data explored here relating to delayed post-session interview responses add an important contribution to the field of science engagement and out-of-school learning. Many previous studies have failed to follow-up with visitors and students beyond the visit itself, predominantly due to logistical issues. This lack of longitudinal data means that these studies are unable to make claims about the lasting impact of experiences. In the current research, however, the data point to long-term impacts of meeting scientists on scientific literacy in the form of lasting science learning outcomes, and impacts on science engagement. Participants reported evidence of engagement occurring between the visit and delayed post-session interview, and indicated intentions for further engagement, supported by evidence of sustained individual interest development for visitors to Nature Live events. The final chapter draws together the conclusions from each data chapter to discuss the overall impacts of meeting scientists on scientific literacy and engagement with science, along with potential avenues for future research and implications for practice.

Chapter 8: Conclusions and implications

8.1 Introduction

In this chapter I summarise the key findings from my study into the impacts of meeting scientists on visitors to the Natural History Museum, London. The impacts of meeting scientists in museum contexts are complex. Impacts are not straightforward, linear changes, but rather they are complex and interrelated. Visitors cannot be sorted neatly according to all of the impacts the session had on them, but rather there are numerous combinations of impacts which are interrelated and multiple ways in which impacts occurred. This study combines an analysis of visitor and student identification *of* scientists, involving attitudes and perceptions, with the analytic lens of identity formation in terms of identifying *with* scientists and interest development. I propose that scientists play the roles of 'everyday experts' – they demonstrate their expertise whilst also revealing aspects of their everyday life such as how they became interested in science, or their hobbies. In this chapter I argue that participants' interactions with these 'everyday experts' will add a new dimension to their science engagement experiences. The combination of both expertise and familiarity may, I suggest, encourage individuals to feel that they too can be informed, confident and interested in science. In this way, interactions with scientists add additional value to scientific literacy and engagement initiatives and experiences. To conclude the chapter, I provide recommendations based on my findings and present implications for research and practice.

8.2 Key findings

The overarching aim of this research was to contribute to understanding of what might encourage and enhance scientific literacy and science engagement. Scientific literacy, in this research, refers to a level of understanding and awareness of science that enables individuals to make informed decisions relating to science and its effect on their lives. Science engagement, in this research, refers to the interest and motivation of an individual to take part in science activities, including visiting museums and science events, watching science television programmes and reading material relevant to science in news articles, online or in magazines.

The current study found that meeting scientists can have a long-lasting impact on visitors' identification *of* and *with* scientists. These long-lasting impacts may contribute to increased levels of scientific literacy and engagement with science.

8.2.1 Summary of contributions to knowledge made by this thesis

This thesis makes contributions to knowledge in three areas, discussed further in the subsequent sections. Firstly, the thesis makes empirical contributions to knowledge in the demonstration and documentation of a broad range of impacts of face-to-face interactions with scientists, relating to identification of and with scientists in particular. These findings include evidence that interactions with scientists may lead to changes in perceptions of scientists and may encourage individuals to recognise shared interests, experiences and connections and identify more closely with scientists. Additionally, this research has demonstrated that some of these impacts of face-to-face interactions with scientists last at least two months beyond the immediate experience. The empirical contributions to knowledge are discussed further in sections 8.2.2 - 8.2.5.

Secondly, the thesis makes methodological contributions to knowledge. The thesis suggests a new way of framing research in the field of museum learning, by drawing on research in science education and drawing together the bodies of work into attitudes and perceptions of scientists, interest and identity development. In this way this thesis offers a new approach to the study of public engagement experiences in museums. This thesis has developed a tool for studying interest in museums, building on previous research by France and Bay (2010), through analysing the topics of visitors' questions. Methodological contributions to knowledge made by this thesis are discussed further in section 8.2.6. Furthermore, this study has gone some way in beginning to conceptualise what 'impact' might mean in the museum learning field – a question grappled with by many museum professionals and researchers. Impact may, in this case, be changes in perceptions and development of science identities, as a result of an interaction with a scientist, leading to development of science literacy and engagement, discussed in section 8.3.

Finally, this thesis makes a theoretical contribution to knowledge in that it introduces the notion of an 'everyday expert' as a way of conceptualising the role of scientists in public engagement with science. This idea can be used to shape further research into public engagement approaches and impacts, as well as providing practical implications, and is discussed in section 8.4.

8.2.2 Identification of scientists: '*I don't think he was quite what I expected. In terms of a scientist*'

This research has found that visitors and students possess multiple co-existing ideas around perceptions of scientists. To explain these multiple ideas I used the notion of a conceptual ecology; the framework of conceptual ecologies supposes that more than one idea about a concept or subject is held simultaneously, and that such ideas are not always congruent or complimentary (diSessa, 2002; Reeve & Bell, 2009). Contrasting ideas held by visitors and students after their interaction with a scientist included the notions that scientists were 'like me' and 'everyday' – '*He actually reminded me of one of our neighbours! … Just a normal chappy*'. But they also included the perception that scientists are experts of high status – '*You get her knowledge and her expertise, she clearly knew her stuff*'.

In addition, students and visitors were found to hold stereotypical ideas about scientists, conforming to well-documented stereotypical images of scientists, yet simultaneously reported that scientists were 'normal people' and not always like the stereotype. Therefore, it would seem that a dual identity of scientists may exist in visitors' and students' minds, which illustrates that perceptions of scientists are not monolithic but fluid and complex. In the literature to date, multiple co-existing ideas have been identified with respect to individuals having multiple understandings of scientific concepts (for example Reeve & Bell, 2009), but not perceptions and attitudes.

Changes in perceptions of scientists were revealed by comparing participants' pre-meeting expectations of scientists to the descriptions given after meeting them. The ways in which participants' perceptions of scientists changed after their attendance at a Nature Live were categorised into ten behaviour groups. The most populated behaviour groups were 'all change', 'emerge; confirm' and 'change; confirm' illustrating that participants' perceptions were altered and some broadened by the experience of meeting scientists – new perceptions were gained, existing perceptions lost, and some expectations were confirmed.

The findings of the current study accord with earlier work that had reviewed attitudes to, and perceptions of, science and scientists. On the whole, attitudes towards science and scientists seem to be increasingly positive: there is a high level of trust in scientists (Brewer & Ley, 2013; Ipsos MORI, 2011), adults are likely to recommend science careers to young people (Losh, 2010) and science and scientists are seen as important (Jenkins & Nelson, 2005). However, there is still a barrier to individuals seeing science as personally interesting or engaging and science careers as being 'for me' (Archer *et al.*, 2010; Bennett & Hogarth, 2009; Cleaves, 2005; Jenkins & Nelson, 2005). This study has, therefore, also aimed at exploring how meeting scientists has an impact on visitors and students on a personal level. It has explored interest, degrees of engagement and the nature of identity change, rather than simply looking at perceptions and attitudes only.

The fact that scientists were more approachable and friendlier than visitors and students had been expecting suggests that personal connections between individuals and scientists were of importance as visitors and students made sense of their interaction with the scientist. These personal connections are discussed further in the next section. Scientists were seen as people who visitors and students were able to talk to on a personal level; participants felt comfortable and confident in interacting with the scientists who they felt were friendly and pleasant. In previous studies, perceptions of scientists have been explored without any face-to-face interaction between participants and scientists.

The focus on interactions with scientists in the current research has enabled a new dimension of perception-forming to be explored further – by interacting with scientists participants had the chance to develop their ideas about how scientists might act in a social situation. These types of perceptions are important in increasing science engagement; an image of scientists as approachable and friendly is arguably more likely to encourage people to take part in future events and activities involving scientists.

8.2.3 Identification with scientists: '*He was like one of the people*'

Visitors and students identified more closely with the scientists after meeting them, identifying common links and connections. Visitors identified shared interests and experiences in terms of their personal and family lives, hobbies, jobs and places they had visited or lived in. Students connected with the scientist they met in terms of making decisions about future study and picturing themselves in similar jobs:

Sampson *It seemed like a nice environment to work in, not over-the-head intellectual or anything. It all seemed relatable almost. That you could just step in and do it if you had more training.* (AL-F group, delayed post-session interview)

In addition, students cited a broadening understanding of what scientists do day-to-day and the types of jobs possible in science, relating this newly developed understanding to their own personal career plans.

Some visitors actively expressed their connections with scientists by positioning themselves closer to the scientist than other visitors attending the event. Referring to ‘the public’ or ‘the rest of the audience’ separated the respondent from the others in the audience. Evidence from field-notes also indicated that the majority of sessions supported, although in some cases provided barriers to, visitors’ efforts to identify more closely with scientists. For example, the audience were sometimes invited to participate in relevant projects or demonstrations.

Through identifying things in common with the scientists and positioning themselves closer to the scientists, visitors and students were developing their own science identities. Meeting scientists thus enabled visitors and students to develop affinity identities as a ‘science person’ through identifying links in common with other ‘science people’, sharing experiences and encouraging participation in associated activities (Gee, 2000). In identifying more closely with the scientist, and less closely with the other members of the audience, visitors are situating themselves within the community of practice of ‘science people’ (Brickhouse *et al.*, 2000; Lave & Wenger, 1991).

The participants in the current research appeared to be developing a science identity characterised by their engagement with science activities and new information. Some of the A-level students were also carrying out identity work with an eye towards their possible future careers and study. I argue that encouraging a broader and more widespread level of scientific literacy and engagement across the population would be a more productive endeavour, in terms of enabling greater numbers of the population to utilise science in their lives, than encouraging more students to enter science careers. Indeed, I would argue that the emphasis should be placed on supporting the development of a ‘science person’ identity rather than a scientist *per se*. I have provided evidence that interactions with scientists may offer opportunities for visitors and students to see themselves as more closely aligned with other ‘science people’, hence aiding their own identity development. In this thesis, I have studied the development of ‘science person’ identities as separate to developing an identity as a scientist or pursuing a science career. This is a key addition to the body of knowledge in this area.

Visitors identified with scientists after meeting them in terms of developing an interest in the scientist themselves and their personal career history. This topic of interest contrasted with other potential areas such as the scientific content of the session or the social and ethical issues around science. As a result of the session, visitors became more interested in the scientists, and asked a higher proportion of questions about the scientist than in previous interviews and during the session. This interest was maintained and in fact increased two months after the museum experience. Students did not exhibit the same interest development, they arrived at the museum with an interest in the scientists that dropped during sessions and post-session interviews but had increased again when interviewed two months after the visit. The development of an interest in the scientists by visitors may indicate a propensity to continue engaging with similar activities and to be interested in conversations with scientists in the future. In terms of developing science identity further, continued engagement with other 'science people' and those who work in science may enable individuals to learn from more expert members of the community of science and become further integrated into the practices of becoming a 'science person'.

8.2.4 Impact longevity: what happened after the museum visit?

A key aspect of the research questions posed at the beginning of this thesis is the question of how long any impacts identified will last, beyond the immediate experience within the museum. Chapter 7 addressed data evidencing broader impacts on participants' learning and engagement with science. These data, from the delayed post-session interviews conducted around two months after the visit, indicated that the impacts lasted beyond the immediate experience for some visitors. These lasting impacts of meeting scientists included lasting learning about the scientific content, changes in attitudes and perceptions relating to science careers for the students, and the development of interest as a result of the session. Visitors and students indicated that they had participated in relevant behaviours following meeting the scientists, including speaking about their experiences to family, seeking related information and returning to the museum.

Individuals are more likely to continue to engage with science and seek out related opportunities and information if they see it 'fitting' with their family and home life (Zimmerman & Bell, 2012) and if they see it as personally relevant and interesting (Kozoll & Osborne, 2004). Evidence of impacts from the delayed post-session interviews suggest that the participants were indeed finding their experiences relevant and interesting, and therefore their developed understandings, perceptions and attitudes are lasting. This study, therefore, not only contributes to the understanding of what impacts meeting scientists might lead to but also how long and in what form these impacts may endure.

8.2.5 Returning to example case individuals: illustrating impacts

The three sections above have addressed the research questions for this study and the relevant key findings. In order to provide a more holistic picture of the impacts of meeting scientists on individuals, I return to three of the example case individuals presented in the findings chapters. Summarising the impacts on each in turn, some idea can be gained of the impact on individual visitors and students of meeting scientists at the museum.

Laurie (NL-Zg). Laurie attended a session on fossils with her husband. She was coded as being part of the 'Emerge' behaviour group, indicating that prior to the session she reported no perceptions about scientists, but following the session she developed perceptions in four of the descriptor categories. In this sense, the experience broadened and developed her understanding around scientists. Laurie had a duality in her perceptions in delayed post-session interviews – she described scientists as both experienced and knowledgeable, and, simultaneously, as normal people and non-stereotypical. Laurie identified with the scientist around particular professional skills, noting that she could understand how difficult it was for the scientist to explain their research to a non-specialist audience and that she often faced the same challenge in her own work. Perhaps it was this identification which led Laurie to discuss the scientist with her colleagues at work, as mentioned in her delayed post-session interview. Laurie developed an interest in the scientist following the session and formulated further questions relating to the scientist's work and personal experiences.

James N (NL-Zx). James N attended a session on edible insects with his two young daughters. He had some perceptions about scientists before the session but none of them were confirmed and he reported different and new perceptions of scientists following the meeting, including that they were relaxed and informal and not like stereotypical images of scientists. These data meant that he was part of the 'All change' behaviour group in terms of impacts on his perceptions of scientists. James N picked up specific knowledge from the session he attended – learning about the amount of bugs in foodstuffs, and repeating this in subsequent interviews. James N also showed evidence of identifying with the scientist compared to the rest of the audience; he spoke about wanting more detail from the scientist as part of the session but distanced himself from other visitors by suggesting that perhaps he was not the target audience for the session and that the level of detail was appropriate for the others in the audience.

Betty Boop (AL-C). Student Betty Boop attended two sessions with her class: one on chocolate and botany and the other on parasites that live on salmon. Betty Boop was in the 'Emerge' behaviour group in terms of the impacts of meeting scientists on her perceptions of scientists – she displayed new perceptions about what scientists were like following the session. Within these new perceptions, Betty Boop had a duality in her ideas. In her delayed post-session interview she described scientists both as experienced and knowledgeable, and helping her to learn. Also in her delayed post-session interview, Betty Boop explained that her experiences had an impact on the way she felt towards other museums, she had noticed more museums and felt more inclined to visit them following her positive experience at the Natural History Museum. Furthermore, meeting the Museum scientist enabled Betty Boop to broaden her understandings of potential careers in science. She said that she had learned that there were more options in science than being a doctor. This broadening of understanding was particularly important for students like Betty Boop, who were still deciding which subject to study at university.

These three examples of individuals illustrate how participants experienced multiple impacts of meeting scientists. Whereas in the findings chapters different areas of impact have been discussed in turn, summarising the example cases in this way provides an overview of how a session may have impacted on an individual in a holistic sense and highlights that impacts were interlinked and multiple.

8.2.6 Studying the impacts of public engagement: methodological insights

Previous studies have attempted to explore the impacts of public engagement activities with varying success. This research builds on previous work in that it has developed methods for studying the longer-term impacts of public engagement with science. The current work interviewed participants two months after the initial visit and, therefore, was able to collect data on any engagement with science undertaken after meeting the scientist. The documentation of impacts beyond the immediate visit is an important contribution of this research as many studies into science engagement and the impacts of museum visits have focused only on the immediate impacts and have not followed up in any way beyond the experience. Researchers have argued that studies need to explore the long-term impacts as well as the immediate impacts, especially as, it has been argued, learning and engagement develop over time (Falk, 2004; Falk *et al.*, 2004; Rennie & Johnston, 2004). Data on post-visit activity is crucial to be able to identify any impacts on science engagement as, in order to influence science engagement, there must be a lasting impact on the interests and motivations of the visitors.

Previously, research into the perceptions of scientists has been dominated by the use of the Draw-a-Scientist test protocol (for example Christidou, 2010; Finson *et al.*, 1995) and surveys (for example Ipsos MORI, 2011; Sjøberg & Schreiner, 2010). Both methods can be limiting in terms of studying a narrow subset of characteristics of scientists. Drawing studies focus mainly on physical characteristics and questionnaires often use predetermined lists of descriptors. The current study explored perceptions of scientists using interview methods which allowed for a more open and broader data set, in this case around perceptions, attitudes and expectations. The descriptors used by the participants in the current study were predominantly about the personality of the scientists rather than their physical appearance. Furthermore, the current study did not reveal other common perceptions such as scientists working in isolation or secrecy, being immoral, or any gender stereotypes, as seen in earlier studies (Christidou, 2011). Rather, the current research provides more detail on the perceptions of scientists, exploring visitors' and students' perceptions in depth. Indeed, the data presented from this study are rich and reveal much about the nature of perceptions of scientists, including the existence of multiple and often contrasting perceptions of scientists.

As well as using an open approach in collecting and analysing interview data, the current study used the questions generated by visitors and students as a research approach for exploring areas of interest. This approach built on the framework of France and Bay (2010) in their study of students visiting research scientists in a laboratory in New Zealand. Although learner-generated questions have been used to study trends in student interest in the laboratory visit context, in the classroom and on online Ask-a-Scientist sites (Baram-Tsabari *et al.*, 2006, 2010), this method had not yet been utilised in a museum context. I have, therefore, used a method through which changes in the interest of individuals may be monitored over the course of a public engagement activity and during the time following. Such an approach may also be triangulated with other methods such as direct questioning about what the participants found interesting and observations of engagement behaviour. Through the approach of using learner-generated questions as a data source, this study offers new insight into how interests are sparked, developed and maintained as a result of public engagement activities in a museum. This study has also revealed the interest profiles of museum visitors and students in terms of the subjects about which they are curious.

This study moved beyond the existing evaluation studies which have looked at the impacts of experiences in the Museum's Darwin Centre. Whereas evaluation makes a value judgement on a specific exhibition or programme with the aim of improving or reporting on that particular initiative, research aims to generate knowledge useful to a wider audience and applicable outside the local context. The current research has made a contribution to knowledge about public engagement more widely, conducted in a specific context but using theoretical framing to draw implications and conclusions which are relevant to other institutions and practice outside the Natural History Museum, London. Thus, the study has novel findings and applications of use to the broader sectors of museum education, science education and public engagement with science with the aim of increasing scientific literacy and engagement.

8.3 Meeting scientists as 'value added' in public engagement with science

My findings suggest that the experience of meeting scientists face-to-face has much to offer in terms of adding value to public engagement experiences and museum visits in particular. I argue that meeting scientists provides additional impacts on scientific literacy and engagement with science compared to other experiences in museums and out-of-school science learning.

8.3.1 Meeting scientists as 'value added' for scientific literacy

Visitors and students developed broader and more positive perceptions of scientists following their meeting at the Museum, further understanding the work of scientists and the nature of science careers, and learned about science topics. These impacts may enable visitors and students to better understand the process of scientific research, make informed decisions about science and to use science information in their everyday lives. Although these types of impacts have been studied in the context of public engagement with science activities and laboratory experience programmes, as discussed in Chapters 2 and 3, the current research presents new understandings of how relatively short interactions with scientists might lead to the development of scientific literacy. In this way, meeting scientists within a museum may be considered to provide 'added value' to the museum visit specifically with regards to the development of scientific literacy.

I have shown that visitors and students demonstrated evidence of gaining long-term science content knowledge relevant to the topic of the sessions they attended, as well as sustained broadened perceptions about science and scientists. These findings build on the understanding of how public engagement may make a lasting impact on scientific literacy, rather than immediate impacts only.

Other out-of-school learning experiences have demonstrated impacts on understanding in science and awareness of the science community contributing to scientific literacy. For example, public physics lectures (Kapon *et al.*, 2010), summer camps at zoological institutions (Bexell *et al.*, 2013), visits to science centres (Bamberger & Tal, 2008a) and laboratory programmes (Luehmann, 2009), have all been shown to increase understanding of science and the nature of scientific research. A more developed understanding of science and the processes of science enables individuals to participate more confidently in the community of science, make informed decisions and utilise scientific knowledge (DeBoer, 2000; Schibeci, 2006). I have highlighted how relatively short-term interactions may make a contribution to a longer-term scientific literacy. This work is significant in that it shows the 'added value' that meeting scientists face-to-face has on scientific literacy compared to other experiences such as watching scientists on television, reading relevant books and websites and visiting museum exhibitions. These comparisons between the value of meeting scientists and other learning experiences were made by the visitors and students in their interviews, and findings from the current study have been compared to literature focusing on other experiences in order to explore the 'value added' by face-to-face interactions with scientists.

8.3.2 Meeting scientists as 'value added' for engagement with science

Visitors demonstrated evidence of engaging with science further following meeting the scientist. For example, visitors and students reported that they had spoken with others about the scientist, sought further information online, bought books on the topic and returned to the Museum. Such evidence of continued engagement with science indicates that the experience of meeting scientists 'added value' in terms of science engagement. Evidence of interest development in visitors is also an indication that the experience of meeting a scientist contributed to visitors feeling inspired and attracted to engaging with science further. Additionally, visitors and students who commented on the relevance of science research, making links to their own lives and seeing it as related to their own experiences, may be more likely to engage with science in the future.

The experience of meeting scientists, therefore, developed engagement in the three elements of cognitive, emotional and behavioural engagement (Finn, 1989; Fredricks *et al.*, 2004;

Hampden-Thompson & Bennett, 2013). In terms of emotional engagement, visitors and students enjoyed the session, formed more positive attitudes to scientists and science and developed new and increased interest in relevant subjects. Contributions to cognitive engagement included visitors and students becoming more knowledgeable and confident around the work of scientists and being inspired to continue their learning about relevant subjects. Visitors and students demonstrated behavioural engagement following the session by, for example, taking part in related activities and discussions and furthering their experience by carrying out follow-up research.

The current study adds to previous research in demonstrating how museum and out-of-school learning experiences may increase engagement with science through the development of positive attitudes, interest and science identity. For example, student interest in space increased following a visit to a space centre (Jarvis & Pell, 2005); visitors found science more personally meaningful and relevant following a visit to a science centre (Rennie & Johnston, 2007); and students developed their own science identities, including new skills and reflecting upon themselves as science learners, following a laboratory visit programme (Roth *et al.*, 2009).

The impacts revealed in the current study relating to attitudes and interests are important as they will determine whether or not the individual will be predisposed to engage with science again in the future. It is important that the personal worlds of the individual support science and science activities if the individual is to continue to be interested in science and seek out further engagement (Zimmerman, 2012). The development of science identity is also important as this is likely to influence whether or not an individual sees themselves as a 'science person', someone who will participate in science activities again in the future and it will impact how they present themselves to others. A developed science identity, and seeing science as 'for me', may lead to continued engagement with science in the future (Archer *et al.*, 2010). Science must be compatible with existing elements of an individual's identity (Aschbacher *et al.*, 2010). Those individuals developing a strong science identity may well see themselves as a 'science person' which might influence their future behaviour and students may even go on to embark on a science career (Krogh & Andersen, 2013).

Participation in a certain area or field involves individuals feeling part of a community involved in relevant practices and activities (Lave & Wenger, 1991). Individuals must identify with others in that community, as in Holland *et al*.'s figured worlds (for example, of alcoholics) (Holland *et al.*, 1998) and have shared experiences and interests as in Gee's affinity identities

(Gee, 2000). The current research adds to the findings of other studies which indicate that out-of-school learning experiences, in particular those with the opportunity to meet scientists, support individuals to feel part of the scientific community and to identify with science and scientists more closely (Farland-Smith, 2009; Fields, 2009; Luehmann, 2009). This work builds on studies of identity work in museums (Rounds, 2006) with a specific focus on science identities. I have shown that visitors and students are able to identify more closely with scientists as a result of a museum experience, compared to the extensive laboratory experiences and programmes which have been studied previously.

Motivation for continued engagement in the absence of external rewards requires intrinsic enthusiasm driven by interest (Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). The current study provides evidence that meeting scientists supports interest development – either sparking new interests or providing opportunities to maintain an existing interest. Supporting interest development may encourage interests to develop from a triggered situational interest operating in the short-term towards a long-term sustained personal interest which will drive future behaviour (Hidi & Renninger, 2006; Krapp, 2002). A development from triggered interest to more sustained interest requires repeated engagement and experiences with the topic, opportunities to reengage and reinforcement of positive feeling towards the topic. Science engagement requires personal interest development if individuals are to feel inspired and motivated to pursue science activities in the long-term, such as visiting museums, watching documentaries or carrying out online research.

The role of interest in engagement with science has not yet been fully explored. By looking at interest and at changing levels of interest I have proposed that triggered, increased and sustained interest are indicators of engagement. I would argue that interest is a more useful concept to use to examine the impacts of public engagement with science and museum learning than attitudes or conceptual knowledge which have previously been used more frequently. Interest relates to the personal curiosity, importance and relevance an individual attaches to a topic, and determines whether or not they are likely to be motivated to engage with it in the future. Knowledge and perceptions are contributors to the likelihood of engagement, for example negative perceptions or misconceptions may mean an individual is less likely to engage with science in future.

To summarise, meeting scientists adds value in terms of challenging perceptions and encouraging the development of new attitudes. In this way, meeting scientists may spark new interest, or be a reinforcing experience in the development of an existing interest. Meeting scientists, therefore, aids science identity development and acts to increase scientific literacy and engagement as a result of adding value to the visitors' or students' experience at the Natural History Museum.

8.3.3 Meeting scientists as 'adding value' to the museum context

In this study, visitors and students met scientists within the context of a museum visit. Visitors and students may have taken part in other activities or sessions, wandered through galleries and exhibitions, or had lunch in one of the museum cafés. Research exploring the impacts of meeting scientists on publics has predominantly been conducted at public engagement events such as discussions, science cafés, science festivals or in laboratory visits such as student work-experience programmes (for example Farland-Smith, 2009). The current study presents an understanding of the impacts of museum experiences whereby visitors are able to interact with an expert and thus where interactions with scientists 'adds value' to museum visits.

The focus of the current study represents the convergence of the two fields of science communication and learning science in out-of-school contexts. The convergence of these fields leverages 'added value' in terms of public engagement with scientists within museum settings. Firstly, the research draws on work from the well-established research literature concerning images and perceptions of scientists and attitudes towards science studies stemming mainly from science education and communication fields. Secondly, the current research also draws from the field of museum education, taking the perspective that museums have a broad range of impacts relating to the visitors' identity rather than cognitive learning outcomes only. Ellenbogen (2013) has discussed the convergence of the fields of science communication and learning outside the classroom; these fields are commonly thought of as separate, particularly in the US, but essentially share aims in terms of increasing scientific literacy and engagement.

It is recognised than not all findings from research in science communication will be directly applicable to museum learning contexts, and vice versa, and the reviews in the current thesis have been constructed with this consideration in mind. For example, science communication research often focuses on scientific issues of societal importance often involving controversy and implications for public life, for example climate science. In contrast, museum exhibitions may illustrate fundamental scientific concepts without covering the societal context. In this way the very subject of research is different – science takes on a different meaning. This difference may mean that research findings are not immediately applicable across fields. However, there are many exceptions to this rather simplistic generalisation, and despite their differences each research field provides much additional value and perspective to the other. Essentially both fields provide a different perspective of looking at events within an individual's learning ecology, shaping their attitudes towards and understanding of science.

The current study demonstrates the potential impact that may be reached when efforts are combined. I argue that the combination of these two fields is a productive and beneficial research approach; considering these fields simultaneously better allows for the impacts on individuals to be explored – individuals do not distinguish between experiences in these two fields, nor are impacts separate or exclusive. Therefore, adopting ideas and literature from both fields enables the research to be more thorough and holistic. The convergence of research in these fields also accords with a learning ecology perspective; thinking of experiences such as museum visits as part of a wider network with cumulative impacts (Barron, 2006a). In combining these strands of research, the current study brings a new, interdisciplinary perspective on the study of public engagement with science.

8.4 Scientists as 'everyday experts': proposing a 'midway' approach to public engagement

In this section I propose that scientists are 'everyday experts' in public engagement. Visitors and students saw scientists as experienced and knowledgeable, but also approachable, friendly and not like traditional stereotypes of scientists would suggest. Visitors and students valued the informal and interactive aspect of the session but also the authenticity and exclusivity of meeting a 'real' expert and being able to learn from them. Thus I propose a new term for conceptualising scientists involved in public engagement activities – 'everyday experts'. This term reflects the balancing act achieved by scientists in that visitors and students value both an expert who is extremely knowledgeable in their specialism and an 'everyday' person with whom they have things in common.

I propose the notion of the 'everyday expert' as a way of conceptualising a methodology of engagement, in that scientists might create effective engagement experiences for visitors when they provide information about both their individual area of expertise and knowledge alongside 'everyday' aspects of their lives such as their hobbies and personalities. The conceptualisation of scientists in this way has implications for the design and understanding of public engagement efforts and further acknowledges the multiple roles that scientists played when interacting with the public.

8.4.1 Scientists as experts: '*I mean the chap was knowledgeable, there's no doubt about that*'

Visitors and students described scientists as experts, as intelligent and knowledgeable. The students and visitors valued the opportunity to speak to a 'real' scientist and the authenticity and exclusivity of meeting an expert. Visitors valued the information they gained from the scientist and their experience and the opportunity to ask them questions.

The idea of scientists as experts accords with the Opportunity Structure Hypothesis of how individuals may provide models or inspiration for others (Sonnert, 2009). In this model, expertise and knowledge are crucial to individuals being identified as potential role models. The contrasting model – the Role Model Hypothesis – predicts that individuals will identify role models of the same gender. As the gender of the scientists was mentioned very rarely in the interviews, the Role Model Hypothesis does not appear to be supported in this research. The study does, however, provide support for the Opportunity Structure Hypothesis in a novel context – that of public engagement in museums.

Sessions were set up in a way that promoted the scientist as the expert in the situation and the audience as less knowledgeable. Visitors and students mentioned the authenticity of the experience of meeting scientists in comparison to others they met in science activities such as teachers or museum educators. Scientists are members of the community of science, meaning that when they speak about science research it is authentic and from first-hand experience. Science educators, on the other hand, see themselves as members of the community of science teaching, as opposed to the community of science, to which they see themselves as newcomers (Hughes *et al.*, 2012). In order to lead to the breadth of impacts on visitors as seen in this research, interacting with someone who sees themselves, and is seen by others, as a member of the community of science may be important.

I have provided evidence that the impacts of meeting scientists and seeing them as experts in their field include increased awareness of science research and careers, learning scientific information, and more positive perceptions of scientists. Seeing scientists as experts, therefore, may develop scientific literacy amongst the individuals who meet scientists. In contrast, seeing scientists as 'everyday' and events as informal and accessible may impact identification with scientists, connections to science and the development of interest, which may influence science engagement.

8.4.2 'Everyday' people: '*Scientists out there are normal people actually, just being really enthusiastic about what they do*'

Visitors and students described scientists as more approachable and friendly after meeting them, compared to what they were expecting. Scientists appeared less stereotypical than visitors had expected. It may have been this 'everyday' nature of the scientist, therefore, and the accessibility of the science, that led to the impacts on visitors' and students' science engagement.

Previous research supports the findings from the current study that meeting scientists enables individuals to see scientists as 'ordinary people' and 'people like us' (Cakmakci *et al.*, 2011; Roth *et al.*, 2009). In seeing scientists as similar to oneself, identifying things in common with them and seeing how the identity of a scientist could fit alongside other aspects of one's own identity, individuals are arguably more likely to engage with science in the future – be that in terms of taking part in science activities and developing interests in science, or in pursuing a scientific career (Archer *et al.*, 2010; Aschbacher *et al.*, 2010; Taconis & Kessels, 2009). In seeing scientists more as 'everyday' people, individuals are more likely to feel that they themselves are someone who may engage with science again in the future, rather than science being something that is for 'others'.

There have been calls for school science to more closely reflect the science that is done in students' everyday lives (Cleaves, 2005; Logan & Skamp, 2013) and for science exhibitions to tie into things that visitors will find familiar and relevant (Barton & Tan, 2009; Zimmerman *et al.*, 2010). Such overlap between science and everyday life, therefore, enables visitors and students to see how science is relevant and important to them personally. In the current study, visitors and students found relevance not in the scientific content of the sessions but in the shared features and experiences they identified with the scientists. This finding suggests that it is important to discuss how the scientist became interested in their work and why others might find it interesting, as visitors were primarily connecting to the person in order to identify relevance in science as opposed to the content of the session.

Participants described sessions as interactive, informal and accessible, and field-notes from sessions confirm that attempts were made to close the social distance between scientists and audiences through invitations to share experiences and participate in the work of the scientist. A perception of events as open and accessible, in this way, is likely to encourage future participation in similar activities. The current research, therefore, provides evidence of how interactions with scientists can offer visitors and students opportunities to relate to science on a personal level, recognise the relevance of science, and identify with scientific experts.

8.4.3 'Everyday experts'

If visitors and students see scientists as experts and 'everyday' people simultaneously, what does that say for future public engagement activities and the involvement of scientists? One way in which these two perceptions of scientists could be incorporated is through promoting the role of scientists as 'everyday experts' or individuals who have a specialist area of expertise but also more regular interests, history, family life and friends.

Visitors and students in the current study seemed to possess a multiplicity in terms of perceptions of scientists. Participants held multiple contrasting views of scientists simultaneously upon which they drew at different times. Visitors and students saw scientists both as experts – interacting with them was a unique and authentic experience – but also as 'everyday' people with whom they had things in common, and sessions with scientists were accessible and interactive. This duality in the range of perceptions could be understood using the idea of a conceptual ecology, enabling visitors to see scientists both as experts and as 'everyday' people simultaneously. Ideas in a conceptual ecology are used to different extents in different contexts and contrasting ideas may be simultaneously accommodated (diSessa, 2002; Reeve & Bell, 2009). It may be that visitors and students had a generalised perception of scientists as experts but that the scientist they personally met contributed to the perception of scientists as 'everyday' and 'normal'. Both sets of ideas can, therefore, be maintained. This dual identity of scientists has not been explored previously – studies into stereotypes of scientists and power balances in dialogue events focus on the first idea of scientists as experts whereas studies into role modelling and science engagement have focused on the relevance of science and science identities, relating to scientists being accessible and 'everyday' people. Bringing these two ideas together to understand visitors' and students' simultaneous perceptions of scientists allows for a deeper understanding of identification *of* and *with* scientists.

The notion of 'everyday' or lay expertise has been used in the context of recognising the expertise of non-scientists and the value of local experience and information alongside scientific research (Irwin & Wynne, 1996). For example, the case cited in Chapter 3, where the local knowledge of sheep farmers was noted as being equally valuable alongside scientific expertise in the period following the Chernobyl radioactive disaster (Wynne, 1992). The term I propose in this thesis – 'everyday experts' – differs in that it promotes the 'everydayness' of experts, rather than the opposite, the expertise of lay people.

I propose 'everyday expert' as new way of conceptualising scientists who take part in public engagement. I primarily suggest that the notion of 'everyday experts' is a way of conceptualising a methodology of public engagement with science; it might be a guiding idea which could shape the development of engagement activities and content scientists decide to discuss. A secondary way in which the notion of 'everyday experts' could be applied is as a criterion for selecting scientists to be involved in public engagement. I would argue that it is important for as broad a range of scientists as possible to be involved in public engagement, to portray the breadth of areas of specialism, roles and personalities science can attract. With such breadth it is more likely that a wider range of public would be able to make links and identify with scientists. I would, therefore, be hesitant of a 'selection criterion' for scientists who could be involved in engagement activities as this could be limiting and narrow the numbers of scientists involved. That said, I could envisage where such a criterion might be of use, perhaps when there is a limited number of opportunities for scientists involved in a particular project or event (for example, the Royal Institution Christmas Lectures). Thus one of my recommendations for future consideration from the findings of the current research is that scientists should adopt the role of an 'everyday expert' in public engagement, primarily in their approach to engagement, and that such a role would have impacts in terms of promoting scientific literacy and engagement with science.

8.5 Implications of this research

This research has identified that there are a breadth of impacts that meeting a scientist may have on visitors and students. These impacts are complex, interlinked and, in some cases, last at least two months after the visit. What follows is a discussion of the implications of this research for future research and practice.

8.5.1 Implications for future research

This research points to many new potential research questions that may be fruitful. The most obvious of these questions involves taking an alternative perspective and looking at the impacts on the scientists of participating in public engagement activities. There have been studies exploring scientists' perceptions of the public and the barriers and motivations for scientists participating in public engagement (for example Poliakoff & Webb, 2007). As yet the impacts of scientists taking part in activities situated in learning environments such as museums have not been well documented (one exception is Blok *et al.*, 2008). Such evidence would, along with the current research, provide a strong case to use in persuading more scientists and policy makers that direct engagement between publics and scientists, done well, has the potential be worthwhile and impactful.

The scientists involved in the current study were all from the field of natural sciences due to their connection with the Natural History Museum. Another extension to the current research would be to explore the impacts of meeting physical science researchers on visitors to museums or science centres. Previous research suggests that physical sciences are more interesting to males than females, whereas for the biological sciences the reverse is true, and these preferences are reflected in what individuals choose to engage with outside school (Jenkins & Nelson, 2005; Jones, Howe & Rua, 2000). Research into the impacts of meeting physical scientists may, therefore, show differences compared to the current study and may reveal gender differences not found in the current research.

The findings of this research have raised the theme of expertise in relation to meeting scientists in a natural history museum. Further research could explore the impacts of meeting experts in other contexts, for example artists in an art gallery or installation, or curators in a social history museum. These types of studies could allow for comparison between experts in other fields and visitors to other institutions, and would build on the conceptualisation of expertise in public engagement. Such a comparison may reveal which impacts observed in this research were due to the subject-specific nature of science and which were due to the scientists being an expert, regardless of subject. Findings of such research would increase our understanding of how to promote literacy and engagement with other subjects, beyond science.

This research positions museums as places where public engagement with science occurs and is impactful. Future research into public engagement may, therefore, include museums as key locations for these activities. Predominantly, the public engagement literature has focused on science festivals, science cafés, public debates and discussions and university open days. Research into dialogue events taking place in museums and science centres has gone some way to bridge this gap, but there is still further work that can be done to make connections between the fields of public engagement and museum studies. Seeing public engagement as part of a visit to learning environments such as museums, science centres, zoos and aquaria allows for the literature from museum education and learning outside the classroom to be referred to alongside research into public engagement and science communication. Studies can, therefore, utilise sound theoretical frames from both fields, for example the museum literature has long discussed what learning is and looks like in museum settings; science communication research has explored attitudes and perceptions specific to science and scientists. Such a joined-up perspective is, therefore, proposed as a promising and holistic approach to studying the impacts of public engagement in the future.

I have taken the perspective that meetings with scientists in museums are experiences from a wider network of learning activities (Barron, 2004, 2006a, 2006b). This perspective has implications for how learning experiences are researched in the future; there needs to be an acknowledgement that learning takes place across many contexts, impacts are cumulative and individuals make links across many learning experiences (Anderson *et al.*, 2003; Griffin, 2004; Tran, 2011). Future research into the impacts of public engagement activities, therefore, requires a consideration of the wider learning ecology in which the experiences take place rather than considering the experience as isolated and as a one-off. The current research, for example, explored how visitors followed-up their experiences of meeting scientists in other aspects of their lives and focused on impacts on science engagement in terms of how likely individuals would be to take part in other science activities in the future.

In order to study engagement with science, interest was used as an indicator of the intention and motivation to engage with science in the future. Using the notion of interest is important as it has been demonstrated to play a large part in motivation and self-directed behaviour; to foster continued engagement with a subject a long-term interest must be present (Hidi & Harackiewicz, 2000). Studying interest using questions to scientists (following France & Bay, 2010) is a useful method that could be applied to many new situations to provide research data. I have provided further evidence that using interest as a theoretical perspective and questions as an indicator of interest is an appropriate and useful method which can be adapted for use in different public engagement contexts. The Natural History Museum now provides Nature Live events to schools via videoconference – often there is one audience with the scientist and host in the Studio and two or three more schools linked up to watch the event from school. The remote schools can email in their questions in real time to ask the scientists. Questions asked to scientists face-to-face could be compared to those asked via videoconference, for example, to see if there are any differences in interest between those watching remotely compared to those in the Studio. This analysis could enable researchers to see the impact of a face-to-face interaction with a scientist, as compared to a remote, perhaps less authentic, 'virtual' encounter.

Finally, there are implications for conducting research as part of a collaborative studentship and in the role of a researcher-practitioner. Such close ties between research and practice throughout the course of a research project addresses many recommendations made for public engagement and museum research (Bartels *et al.*, 2010; King & DeWitt, 2013; Rounds, 2007). Through conducting research in close proximity to practice, this study has provided mediation between the production and use of research in terms of knowledge mobilisation (Levin, 2013). At the start of this research, a modified Delphi study was conducted in order to consult Natural History Museum practitioners on research areas they felt were most important to ensure the research focused on problems relevant to museum practice (Seakins & Dillon, 2013). Partly as a result of this exercise, the research findings have been of interest to professionals in the museum and the wider field.

8.5.2 Implications for practice

The findings of this thesis have been presented to scientific and public engagement practitioner communities at the Natural History Museum in London, to scientific members of the Institute of Zoology and the education team at the Zoological Society of London, at Naturalis Biodiversity Centre in Leiden, and at the Ecsite (European network of science centres and museums) conference in 2013 and 2014. Participants in these presentations have indicated that the findings and patterns emerging from the data resonate with them from their practical experience and that the conclusions, interpretations and recommendations from this research are of use and interest to them in their own work. Thus I am confident that the current research has implications relevant to museum education and science engagement practice. I discuss implications for practice in two strands; first, the roles of scientists in public engagement; second, for the public engagement with science sector more broadly.

i) What roles should scientists play in public engagement?

Scientists played a double role in experiences at the Natural History Museum attended by students and visitors: experts and 'everyday' people. In taking these roles in the public engagement event studied, scientists had the opportunity to influence visitors' and students' attitudes to science, perceptions of scientists and also facilitating access to science. The identification of a multiplicity of perceptions of scientists in the current study provides evidence for the roles scientists *do* play and leads to recommendations of the roles scientists *should* play in public engagement. Taking the new perspective that the role of 'everyday experts' is valuable and potentially highly useful, I propose three recommendations for consideration stemming from my research.

Be cautious with the term 'expert'. The image of scientists as experts and as 'knowing all the answers' is problematic in terms of encouraging science engagement and literacy amongst non-experts. Providing scientists with such status widens the gap between them and their audience. Without the 'everyday' element of the dual role of scientists, and seeing science as something for them, accessible and interesting, lay individuals are unlikely to be motivated and inspired to engage with science further. Portraying scientists as experts reinforces the idea that only certain people can enjoy and engage with science whereas non-experts can, in fact, engage with socio-scientific issues and debate the implications and uses of science without being scientists themselves. Scientists might be presented as people with expertise but care should be taken to ensure that they are still accessible to non-experts who can make links to them and see that science is interesting to 'everyday' people like them – expertise must be attainable if others are to be encouraged to engage with science in the future.

Interestingly, although portraying scientists as experts may be detrimental to engagement for some visitors, participants in other dialogue events appreciated the expert knowledge of the scientist and stated that it was necessary to hear new information from scientists to be able to participate in dialogue (Davies *et al.*, 2009). Expertise has also been demonstrated as being necessary in terms of facilitating attitude change in a positive direction (Zorn *et al.*, 2010). It is therefore recommended that in public engagement activities involving interaction with scientists, the knowledge and specialism of the scientist is made clear and available to the audience whilst ensuring that the individual researcher is accessible and friendly. This outcome might be achieved, for example, through encouraging the audience to ask questions to gain new information from the scientist as a reliable and first-hand source of information. Scientists should, therefore, play the role of 'everyday' experts in public engagement, highlighting their particular expertise but to also acknowledge the more 'normal' aspects of their life.

Attracting an audience, on the other hand, to an event with an 'everyday person' could also be difficult – what is the selling point for visitors if they believed that the scientist will be just like someone they might meet elsewhere? There needs to be a balance in the portrayal of scientists, as experts on the one hand and as 'everyday' accessible people on the other. This balance is important in order for the experience to be special, memorable and impactful for the visitors attending, whilst allowing them to draw their own connections and links to the scientists.

Promote the individuality of researchers. Many of the impacts associated with meeting scientists were concerned with the individual scientists who visitors and students encountered. Where perceptions of scientists were changed as a result of the meeting, it was due to characteristics of the individuals concerned, for example their passion for a certain topic or, their background and personality. Visitors and students identified with individual scientists, not necessarily the field of science as a whole. Identifying with individuals was a step towards further engagement with science more broadly. The connections that visitors and students made were to the person they met, their career, characteristics, their family life outside of work, or the places they personally visited on fieldwork. These are all aspects which are personal to the individual and will change between scientists and members of the audience.

In promoting the variation between, and individuality of, scientific researchers, there is less of a risk of making generalised comments which force stereotypical perceptions to be reinforced. Talking about scientists as individuals means that any variation between researchers is identified and there is more space to consider their personal story. Focusing on the individuals in science is a strategy that has been encouraged to demonstrate the diversity and variety in science (Wong, 2002). The findings of the current research provide evidence to suggest that an individualistic approach to public engagement could be impactful. Scientists might consider, therefore, emphasising their individual experiences and journeys as part of their presentations.

Be cautious with the term 'scientist'. In presenting researchers as individuals and emphasising the diversity within the community of science, questions are raised as to whether using the generic term 'scientist' to describe the researchers people are meeting is in fact too broad. Using other terms such as 'natural history researcher' may enable visitors to develop their understanding of this specific area of science in more depth. Students demonstrated broadened understanding of careers in science relevant to natural history following their interactions with the museum researcher: many of those interviewed stated that they had not realised such jobs existed and had only considered the traditional science careers thus far, including medicine and working in a laboratory. In considering the roles of scientists in public engagement as individuals, first and foremost, a shift is required in how these events and individuals are discussed and defined in order to better capture the diversity between each individual involved. Scientists might, therefore, play the role of natural history researchers, entomologists, or tape-worm specialists for example, and greater differentiation between researchers in different fields of science should be adopted in communications.

To summarise, scientists played a variety of different roles when engaging with visitors through Nature Live events and behind-the-scenes days. A question arises, however, as to what roles scientists are *not* playing when interacting with the public and whether there are any opportunities missed when developing these types of public engagement events. Whilst scientists clearly acted as role models for the students in terms of inspiring students to consider broader careers in science, there is no evidence that female scientists acted as particular role models for female students and male scientists for male students. One explanation for the lack of gender-specific role modelling in the current research may have been the one-off nature of the session – visitors and students were unlikely see the same scientist for a second time if they visited again, repeated interaction may have facilitated further role model development as has been noted in previous research (Buck *et al.*, 2008; Hughes, 2001). Scientists, however, played other roles in inspiring careers in science, in terms of increasing awareness of science jobs and understanding of the processes of science.

ii) Further implications for public engagement practice

In order to achieve the balance necessary to present scientists as 'everyday experts', I suggest that a 'midway' approach to public engagement with science would be beneficial. By 'midway' I suggest that public engagement should be positioned on the continuum between purely deficit, one-way, transmissive science communication at one end and dialogic, two-way public engagement at the other. A 'midway' approach would allow for the knowledge and expertise of scientists to be explicit and for new information to be shared with the audience. It would also call for scientists being presented as accessible and approachable and would promote interactive and informal sections where audiences could ask questions and share their own experiences. Such an approach could incorporate the aspects of meeting scientists that visitors and students valued in the current study which led to such diversity and longevity of impacts. This 'midway' approach might ensure that meeting scientists provided 'added value' in the development of scientific literacy and engagement.

The impacts of meeting scientists reported in this thesis are encouraging in terms of promoting realistic and positive images of scientists. There is a small risk, however, that these findings support a deficit model of science communication that would suggest that 'getting scientists out there' will change the opinions, attitudes and images of scientists. Although the current study does indeed suggest that meeting scientists leads visitors and students to see scientists in a more positive light – for example describing them as 'more approachable', 'passionate', 'enthusiastic', 'interesting' and 'nicer' compared to expectations – the impacts are more complex than a simple linear causal relationship would suggest. Caution should, therefore, be taken when interpreting the findings of this study to include the complexity of the impacts together and not suggest that merely placing a scientist in front of an audience will lead to more positive perceptions of scientists in general.

There are numerous implications for developing discussion and dialogue events involving scientists stemming from this research. In Nature Live events, as well as in many other dialogue and discussion events, there is an imbalance of power (Davies, 2013). The way events are framed suggests that the scientists are of high status, particularly in relation to the host and audience, helping to promote the notion that scientists are somehow separate from 'normal people' and that meeting them is a 'special' experience. Such a format is actually valued by audience members who appreciate the exclusivity of meeting a scientist but caution should be taken if the aim is to develop a truly dialogic event in which all parties are of equal status, not to promote an image of scientists as 'other' or 'better' than visitors. There are also implications for scientists in deciding what to talk about when taking part in public engagement activities – for example this research highlights that the audience are interested in personal stories, how individuals got into their field and what interests them about it as well as new or surprising scientific information which can be remembered easily and used to spark conversations.

8.6 Conclusions

To return to the research questions, this study has shown that meeting scientists leads to complex impacts on visitors' and students' identification *of* and *with* scientists. Museum discussion events are fruitful places in which to facilitate these interactions between publics and scientists. Interactions with scientists led to impacts on identification of scientists, with two themes emerging – scientists as possessors of expert knowledge and scientists as 'everyday' and 'people like me'. Visitors and students also identified more closely with scientists following meeting them, identifying links, common interests and shared experiences, developing their own science identities as a result.

Meeting scientists provided ‘added value’ in terms of further enhancing scientific literacy and engagement. Following interactions with scientists, visitors and students developed new interests, had broader understandings of what scientific research might entail and reported increased awareness of science careers. Participants took part in further engagement with science in a variety of ways. Impacts were long-lasting, evident up to two months after the visit.

I have proposed that the role of scientists in public engagement should be one of an ‘everyday expert’, someone who is extremely knowledgeable and experienced within their area of specialism, yet also approachable, friendly and able to share stories about other aspects of their life outside of science. Portraying scientists as ‘everyday experts’ requires a ‘midway’ approach to public engagement – an approach between a traditional transmission model and the open two-way dialogue model.

I have shown that meeting scientists supports the development of scientific literacy and engagement in visitors and students and leads to complex and long-lasting impacts. This research has contributed to the knowledge of the impacts of public engagement experiences involving direct interaction with scientists, situated within museum settings. The study has implications for future research and practice which I have described. I look forward to contributing to further work in this field.

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Appendices

Appendix I

Outcomes of the modified Delphi study (Seakins & Dillon, 2013)

Seven potential research themes were identified by participants in the modified Delphi study (in order of preference):

- What is the impact of meeting and interacting with a real scientist?
- What visions of scientists are portrayed [in the Darwin Centre, Natural History Museum, London]? What are the impacts of these?
- What are scientific role models? How [and in what ways] are Museum scientists role models?
- To what extent does the Darwin Centre humanise science? What is the impact of this?
- What is the impact of public engagement on the scientist taking part?
- Does the Darwin Centre support science as culture?
- Does the Darwin Centre support or challenge people's worldviews?

Appendix II

Nature Live interview schedules

Key questions in normal font, selection of additional prompts and notes to interviewer in italics, links to research questions in bold.

Nature Live: Pre-session interview

Provide participant(s) with the information sheet and give time to read through.

Present the consent form and ask if participant(s) is/are happy to proceed. Do they have any questions? Collect in signed consent form(s).

Double check if participant(s) mind the interview being recorded. If fine, switch on recorder.

Start interview.

- Is this your first time in the Natural History Museum? *If no, how many times have you been before?* Have you attended a Nature Live event before?
- Did you know that scientists worked at the Natural History Museum?
  If yes, what do you know about what they do?
  If no, what do you think they might do here? **Identification of scientists**
- What were your motivations for coming along to the Nature Live event today? *What are you hoping to get out of it? What made you want to attend the session? Who (if more than one participant) wanted to come? Is this [topic of event] a topic you are particularly interested in? Have you been to a Nature Live event before and that made you want to return?* **Impacts of meeting scientists (expected impacts of session)**
- What are you expecting the event to be like today? *What do you think the session will include? What do you think will happen? What do you hope it will be like?*
- What are you looking forward to most about the *session? Is there something you are particularly hoping will be covered or included? What do you think will be the best bit? What do you think will be the most memorable, interesting or exciting part?* **Impacts of meeting scientists (expected impacts of session)**
  Note: here draw on any other experiences interviewee has mentioned so far – e.g., if they have mentioned they have attended a Nature Live before, or any similar sessions or activities – what are you hoping you might see or experience again?
- What are you expecting the scientist to be like? *What might they look like, how might they present, what kind of person do you think they will be? Do you come*

across many scientists (e.g. friends/family that work in science?) **Identification of scientists**

- During the event you will have the chance to ask the scientist some questions. What do you think you would like to ask the scientist? *Note: If participant looks nervous say that they don't have to ask any questions in the session if they don't want to, I'm just interested in what they might be interested in asking. Is there anything else you would like to ask about? Do you have any other questions?* **Identification with scientists and impacts on interest**
- What are you hoping to get out of the session today? *Note: this question was sometimes difficult for participants for whom English was not their first language, may need prompting more.* **Impacts of meeting scientists (expected impacts of session)**
- Is there anything else you would like to say about what you are expecting or hoping the event and scientist will be like?

Following the interview check with participant if they are happy to meet after the session to tell me what they thought about it. Say that there is no rush to come out – take their time if they would like to speak to the scientist or host at the end. I will meet them outside the studio whenever they are ready.

Nature Live: Post-session interview

When participant(s) come(s) out of the studio check that they are still happy to speak for a little while, and show them back to the adjacent gallery to sit down. Check if they are happy for me to record the interview again.

- Firstly, what did you think? *What were your thoughts about the event? What was it like? What happened?*
- What did you like or enjoy about the event? *Why did you particularly enjoy that? What made it enjoyable?* **Impacts of meeting scientists**
- What did you not like or not enjoy about the event? *What did you not like about that aspect, what could have improved it? Was there anything you would change about the session or hope to see different next time?* **Impacts of meeting scientists** *Note: some participants require more prompting than others, on this question in particular more than others, as it asks for negative feedback. Repeat if necessary here that you do not develop the sessions, that their feedback will be anonymous, and that feedback is used to improve the sessions and make them more enjoyable for others so all feedback is valuable – positive and negative.*

- What did you find most interesting about the session? *What was the best bit? And why, what made it interesting?* **Impacts of meeting scientists**
- What did you get out of the session? *Did you gain anything from the session? Note: this question was sometimes difficult for participants for whom English was not their first language, may need prompting more – did you learn anything, make you feel differently about anything, see anything you had not seen before?* **Impacts of meeting scientists**
- *Could ask here how it compared with any previous sessions they had attended*
- Tell me about the scientist you met. *How would you describe them? What were they like, how did they present, what did they look like, how did they act?* **Identification of scientists**
- What did they speak about? **Identification of scientists**
- Was there anything unexpected or surprising about the session or the scientist you met? *Anything that you had expected to be different? Did anything surprise you?* **Identification of scientists**
- If the scientist came and sat down with us now, what other questions would you like to ask them, or what might you like to hear more about? **Identification with scientists and impacts on interest**
- Do you think the session has made you think or feel any different? *This could be in relation to science, the scientist, the museum?* **Impacts of meeting scientists**
- Are you a scientist yourself? Do you have a scientific background? *Would you say you had an interest in science (outside of work if also working in science)? Do you often visit museums like the Natural History Museum?* **Identification with scientist**
- Is there anything else you would like to add or things you would like to say?

Turn off recorder.

Ask participants to fill in very short questionnaire for additional descriptive data about themselves, including age, who visiting with etc.

Remind the participant about the follow-up interview, and ask for an email address and/or phone number to contact them in two months.

Thank them for their time.

Nature Live: Delayed post-session interview

Ask participants if this is still a convenient time, check they are still happy to conduct the interview. Check they are ok if I record it – if so turn on recorder and start interview.

- Let's start by talking about what you can remember about your visit to the Museum, particularly the session where you met the scientist? *Can you tell me what the session was about? What happened?* **Impacts of meeting scientists**
- What did you find most interesting about the session? *What (if anything) in particular do you remember enjoying about the session? Prompts – content/format/experience* **Impacts of meeting scientists**
- What can you remember about scientist you met? *What were they like? How did they present their work?* **Identification of scientists**
- What did they speak about? **Identification of scientists**
- Have you thought about the visit since? *If so, what made you think of it? What did you think about?* **Impacts of meeting scientists (on attitudes/behaviour)**
- Have you spoken about the visit since? *If so, to whom? What did you speak about* **Impacts of meeting scientists (on behaviour)**
- Have you followed up the session in any way? *For example has it cropped up in your work or other activities? Have you looked up anything further?* **Impacts of meeting scientists (on behaviour)**
- Have you thought about any more questions you would like to ask the scientist? *If you met them again what would you want them to talk a bit more about?* **Identification with scientists and impacts on interest**
- What do you feel that you got out of the session? *Did you gain anything from the session? Note: this question was sometimes difficult for participants for whom English was not their first language, may need prompting more – did you learn anything, make you feel differently about anything, see anything you had not seen before?* **Impacts of meeting scientists**
- Do you think the session has made you think or feel any different? *This could be in relation to science, the scientist, the museum?* **Impacts of meeting scientists**
- Do you have any plans to return to the Museum? *If so, do you think you would go to another Nature Live event? What makes you want to/not want to attend another one?* **Impacts of meeting scientists and identification with scientists**
- Is there anything else you would like to add or things you feel we have not yet covered?

When I am writing up my research I will anonymise all of the data, as we spoke about when we first met. In order to anonymise your responses I am asking participants to pick their own pseudonym, or fake name. What would you like your pseudonym to be?

Thank you so much for taking part.

Appendix III

A-level groups interview schedule

A-level groups: Pre-session interview

Provide participant(s) with the information sheet and give time to read through.
Present the consent form and ask if participant(s) is/are happy to proceed. Do they have any questions? Collect in signed consent form(s).
Double check if participant(s) mind the interview being recorded. If fine, switch on recorder.
Start interview.

- What are you expecting the day on Monday to be like? *What do you think the session will include? What do you think will happen? What do you hope it will be like? What have you been told from your teachers?* **Impacts of meeting scientists (expected impacts of sessions)**
- Have you been to the Natural History Museum before? *If yes, when? How many times? What have you seen before? Have you been to a Nature Live event before? If so, what was it like, what did you think about it?*
- Did you know that scientists worked at the Natural History Museum?
  If yes, what do you know about what they do?
  If no, what do you think they might do here? **Identification of scientists**
- What are you expecting the scientists to be like? *What might they look like, how might they present, what kind of person do you think they will be?* **Identification of scientists**
- What are you looking forward to most about the session? *Is there something you are particularly hoping will be covered or included?* **Impacts of meeting scientists (expected impacts of session)**
- What do you think will be the best bit? *What do you think will be the most memorable, interesting or exciting part?* **Impacts of meeting scientists (expected impacts of session)**
- Have you chosen which scientist you will be meeting in the morning session (or was this chosen for you by your teacher? What made you want to meet that one in particular? **Identification of and with scientist**
- Do you meet many scientists as part of other activities, either in or out of school? *Have you had talks given by scientists? Have you been on other trips to scientific*

institutions? If so what have the scientists been like that you have met? What have you thought about those experiences? **Identification of scientists**

- During the event you will have the chance to ask the scientist some questions. What do you think you would like to ask the scientist? *Note: If participant looks nervous say that they don't have to ask any questions in the session if they don't want to, I'm just interested in what they might be interested in asking. Is there anything else you would like to ask about?* **Identification with scientists and impacts on interest**
- What are you planning on doing after you finish college – in terms of studying or working? *Probe as to whether these plans involve science, what they feel about a career in science. If they have not yet decided, whether the options include science in any way or if it has been ruled out?* **Identification of and with scientist**
- Is there anything else you would like to say about what you are expecting or hoping the event and scientist will be like?

Following interview talk about the plan for their A-level day – mention that I will be there and will come along to the sessions. Ask if the students mind if we talk for about 15 minutes at lunch time, straight after the Nature Live event.

A-level groups: Post-session interview

When participants come out of the studio check that they are still happy to speak for a little while, and show them back to the adjacent gallery to sit down. Check if they are happy for me to record the interview again.

- Firstly, what did you think? *What were your thoughts about the event? What was it like? What happened?*
- What did you like or enjoy about the event? *Why did you particularly enjoy that? What made it enjoyable?* **Impacts of meeting scientist**
- What did you not like or not enjoy about the event? *What did you not like about that aspect, what could have improved it? Was there anything you would change about the session or hope to see different next time?* **Impacts of meeting scientist** *Note: some participants require more prompting than others, on this question in particular more than others, as it asks for negative feedback. Repeat if necessary here that you do not develop the sessions, that their feedback will be anonymous, and that feedback is used to improve the sessions and make them more enjoyable for others so all feedback is valuable – positive and negative.*
- What did you find most interesting about the session? *And why, what made it interesting?* **Impacts of meeting scientist**

- What did you get out of the session? *Did you gain anything from the session? Did you learn anything, make you feel differently about anything, see anything you had not seen before?* **Impacts of meeting scientist**
- *Could ask here how it compared with any previous sessions they had attended or any other scientists they had met* **Identification of scientists**
- Tell me about the scientists you met. *What were they like, how did they present, what did they look like, how did they act?* **Identification of scientists**
- What did they speak about? **Identification of scientists**
- Was there anything unexpected or surprising about the session or the scientist you met? *Anything that you had expected to be different? Did anything surprise you?* **Identification of scientists**
- If the scientist came and sat down with us now, what other questions would you like to ask them, or what might you like to hear more about? *Do you have any more questions?* **Identification with scientists and impacts on interest**
- Do you think the session has made you think or feel any different? *This could be in relation to science, the scientist, the museum?* **Impacts of meeting scientist**
- Remind me what your plans are for studying/careers after college? *Do these plans involve science?* **Impacts of meeting scientist and identification with scientist**
- Is there anything else you would like to add or things you think we have not yet covered?

Thank you for your time today. I will arrange a time to come back into school and speak with you in about two months, time – just to have another chat with you about the sessions today once you have returned to school.

A-level groups: Delayed post-session interview

Check if students are still happy to speak with me and that they are ok if I record it – if so turn on recorder and start interview.

- Let’s start by talking about what you can remember about your visit to the Museum, particularly the sessions where you met the scientists? *Can you tell me what the sessions were about? What happened?*
- What did you find most interesting about the sessions? *What (if anything) in particular do you remember enjoying about the sessions? Prompts – content/format/experience* **Impacts of meeting scientist**
- What can you remember about scientists you met? *What were they like? How did they present their work?* **Identification of scientists**

- What did they speak about? **Identification of scientists**
- Have you thought about the visit since? *If so, what made you think of it? What did you think about?* **Impacts of meeting scientist (on attitudes and behaviour)**
- Have you spoken about the visit since? *If so, to whom? What did you speak about?* **Impacts of meeting scientist (on behaviour)**
- Have you followed up the session in any way? *For example has it cropped up in your lessons or other activities? Have you looked up anything further?* **Impacts of meeting scientist (on behaviour)**
- Have you thought about any more questions you would like to ask scientist? *If you met them again what would you want them to talk a bit more about? Do you have any more questions?* **Identification with scientists and impacts on interest**
- What do you feel that you got out of the session? *Did you gain anything from the session? Did you learn anything, did it make you feel differently about anything, did you see anything you had not seen before?* **Impacts of meeting scientist**
- Do you think the session has made you think or feel any different? *This could be in relation to science, the scientist, the museum?* **Impacts of meeting scientist**
- Do you have any plans to return to the Museum? *If so, do you think you would go to another Nature Live event? What makes you want to/not want to attend another one?* **Impacts of meeting scientist and identification with scientist**
- Remind me what you are planning on doing following college – in terms of work or studying? *Probe whether these plans involve science, how they feel about science careers?* **Impacts of meeting scientist and identification with scientist**
- Is there anything else you would like to add or things you feel we have not yet covered?

When I am writing up my research I will anonymise all of the data, as we spoke about when we first met. In order to anonymise your responses I am asking participants to pick their own pseudonym, or fake name. What would you like your pseudonym to be?

Thank you so much for taking part.

Appendix IV

Example of coded interview transcript.

In this appendix two coded transcripts from individuals attending the same Nature Live session have been combined to provide more examples of coding rather than presenting only one individual. Colour coding has been used to illustrate how transcripts were coded for each individual:

Kate (NL-L) Example case individual from Chapter 5

Bob (NL-L)

Individual	Transcribed interview (coded sections highlighted)	Code
[Start of pre-session interview recording 7/1/2012]		
Interviewer	[Continued from conversation before interview began] So are you here for the day are you, just visiting? And have you been to the Natural History Museum before, recently?	
Kate	Not recently, I think when the last time I was here was probably when I was at primary school	
Bob	Yeah	
Interviewer	And so you haven't been to one of our Nature Live events before, that's the event you are just about to go to, given by one of our Museum scientists, did you know before you came that there were scientists working at the museum?	
Kate	No, no. Not within the museum no?	
Interviewer	Did you, what did you know about -	
Kate	I thought that maybe they would partner up with the museum, for their academic research, if they are going off you know looking at I don't know, some kind of, if they are going exploring some, somewhere. And then bringing back	Understanding the work of scientists

	their research, having a partnership that kind of thing	
Interviewer	Yeah, yeah. So that happens as well, but there are actually about 350 scientists who work here, in all directions [pointing up at offices], in different offices and things, so that will be one of them that you meet today, he works on volcanoes. So you didn't know, you didn't know the event was happening today?	
Kate	No	
Interviewer	No, and when I mentioned volcanoes, you kind of, you looked very interested - why was that?	
Kate	Erm, my whole topic for this term, for this whole term is volcanoes.	Making links: personal links to job/study
	So that's it, perfect, to actually meet someone who is going to give a talk on, on volcanoes is just brilliant.	References to the experience/event: Authentic, unique and exclusive experience
Interviewer	Yeah, so you are hoping that you will get something that you can use in your job as a primary school teacher. Brilliant, and are you guys interested in science? Vaguely, not very much?	
Kate	Yeah I suppose so, yes	
Interviewer	Yeah, do you come to museums very much or?	
Kate	I think we last went to well, I go to museums quite a lot. The Florence Nightingale Museum, British Transport Museum	
Bob	I'm sure we went to the Science Museum once	

Kate	Science Museum we went to	
Bob	That's probably with your school trips isn't it	
Kate	But I enjoy going round, but I usually have to go for risk assessments	
Interviewer	Yeah and investigate what's going on, but then at least you can look around as well. So what are you expecting the scientist to be like that you meet today?	
Kate	Erm, I'm expecting a really interesting talk.	Interest as motivation
	Probably be talking about his actual research, and what he's found out, and how that's going to affect what we know about volcanoes.	References to the experience/event: Authentic, unique and exclusive experience
Bob	Erm, quite in-depth I'm sure. Hopefully he will be able to explain his things in layman's terms	Descriptions of scientists: pre-session expectations
Interviewer	What do you think the best thing about it will be?	
Kate	Erm hopefully, I'm quite a visual learner, so I'm hoping that there will be, erm, some maybe some film clips or something, erm, while he's talking there might be some sort of, I suppose maybe a powerpoint thing, or some kind of visual to go with it	
Bob	Perhaps some specimens as well, to pass round, I don't know	
Interviewer	Yeah, some of the things that he might work with maybe	

Bob	Yeah rocks and stuff, volcanic material	
Interviewer	I think you both might be lucky there, I saw it earlier! [laughs] So you will get the opportunity to ask the scientist questions while you are there, can you think of any questions off the top of your head now that you might want to ask him?	
Kate	Oh [pause] how many are in his team, if he did work in a team. How long he's been erm, looking at this specific volcano for.	Questions: Personal
Bob	I probably won't ask any questions	
Interviewer	No, none that come to mind at the moment?	
Bob	No	
Interviewer	And what do you hope to get out of it?	
Kate	I would like, it would be more to pass the knowledge on to my class I think. So I've been trying to read up on it a bit myself because it's the first time I've taught this topic, so erm, I'd quite like to be able to take some of what I've learned today to pass onto my class. What about you?	Learning as motivation
Bob	Yeah, I'm quite keen to sort of find out about gases that are emitted, from volcanoes. And how they compare to sort of our CO_2 impact on the environment. So hopefully he would be able to characterise some of that, you know that proportion difference between an active volcano and the population of the UK, or some kind of comparison like that	Learning as motivation
Interviewer	Yeah, is that something that you are quite interested in, the environmental impacts of?	
Bob	Yeah, I mean, I don't - the other day about the Icelandic volcano, and how obviously that emitted quite a lot of, gas,	

	but compared to how much would be saved from all the aircrafts being grounded, erm, is quite a big difference. I didn't know if that was true or if that was a myth or	
Interviewer	Yeah, not sure, yeah. And is there anything else you wanted to say about what you are expecting before you go in?	
Kate	No, I'm just feeling quite excited, I'm like wow - actually get to sit in a talk, with a [scientist]	References to the experience/event: Authentic, unique and exclusive
Bob	Wouldn't expect in in coming to a museum, to have a scientist right there and then. Usually it's just video screens, and stuff to look at	References to the experience/event: Compared to other experiences
Kate	Yeah it's going to be quite hard to actually, yeah you know this is what someone does for a living, and they're here, while we're here, so that's really good	References to the experience/event: Authentic, unique and exclusive experience
Interviewer	Yeah, do you come across many scientists, sort of elsewhere, do your friends or -	
Kate	Erm, one of the teachers that I work with, her husband is um, I might be getting him to come in and talk about his PhD work that he's doing at the moment, because he works, he's working with rocks and things, yeah. So and my uncle again, he's a scientist, so yeah, we've got kind of family and friends.	
Bob	Yeah see geologists now and again.	
Interviewer	Do you have scientific backgrounds yourselves?	
Bob	Yeah, I mean I'm an engineer, so I've been to uni, and been	Personal scientific

	around geologists and other science based, people.	background
Kate	Whereas my degree is psychology, so it's more social science	Personal scientific background
Interviewer	Yeah, brilliant - ok	
[End of pre-session interview recording 7/1/12]		

[Start of post-session interview recording 7/1/12]		
Interviewer	OK so what did you think?	
Bob	It was pretty good. Yeah, erm sometimes quite hard to understand his accent	Description of scientist: post-session
Interviewer	Mmm yeah it's quite strong isn't it	
Bob	You still get what he's getting at, though, which was very interesting	Description of scientist: post-session
Kate	I thought it was brilliant. Erm, didn't expect the, well obviously I came here for a risk assessment, and I thought it was fantastic, and I spoke to, was it Maurice?	
Interviewer	Oh yeah, the host	
Kate	And so I'm going to email about whether we could do something, because he said that if I emailed what we were doing at school, in the education department of the museum, I'd be able to do something with my class	Continued engagement (intentions to return to NHM)
Interviewer	Yeah, that would be really good then! And do you feel that you got anything out of it as well?	
Kate	Definitely, I mean obviously lots of people know about Etna. But it was really interesting about Stromboli, and little	Specific learning

	Stromboli as well	
Interviewer	Yeah and so you liked learning about new, other volcanos, rather than just the ones that you know about already?	
Kate	Yeah that was good	
Bob	It seems like it would be easy for kids like that a whole class to understand, clearly explained	
Kate	I really liked how he, when he got the stick, and just how it breaks. And I might be able to do that with my class when I'm explaining that to them. So I've got some ideas about how I can explain it to children, so that was good.	Making links: personal links to job/study
	I thought it was very accessible, his talk today was very accessible. Obviously his type of work it could have been about the chemistry and the different compositions, and you know things like that. I thought it was really good yeah, it was understandable	References to the experience/event : Accessibility of information
Interviewer	Good that's really good. Was there anything that kind of surprised you or was unexpected?	
Kate	Erm, I think the little Stromboli, that was – I didn't realise about that. So that was a really good thing to learn about, understand that	Specific learning
Bob	Yeah, I didn't know how volcanoes eroded in that way. You know being left with the core staying there whilst everything else around it eroded. I supposed it would erode from the inside out if that made sense, so yeah	Specific learning
Kate	And then how it erupts every 20 – 25 minutes, erm I didn't know that, so I've learned lots just from that 20 minutes talk, yeah it was really good	Specific learning
Bob	Yeah I was surprised	

Interviewer	What do you think the best bit about it was?	
Kate	Erm I thought, the little volunteer with the pumice, that was just, you know that really just shows you how different they all are, and there's not one that will ever be the same as the other, and just you know, the differences in the chemistry of the magma, and how the thick magma will produce different. Oh and volcanic bombs – my class are going to love that – they are absolutely going to love that! I'd never heard about that before and that was really fun as well, but I just didn't know anything about that, and I've been reading up on volcanoes on the subject books that I've got in school, and volcanoes for children books and things and trying to read up on it. But that's going to be fun learning about those I think	
Bob	Yeah all the pictures and videos are great. I think some of the videos were a bit short, I dunno obviously you have to try and compact things into however long it was, 20 minutes or so, but yeah I liked the video clips, the orange magma flowing it was great	
Interviewer	Yeah, you were both saying you were quite visual people.	
Kate	Yeah	
Interviewer	And I asked you before if you had any questions for the scientist, and then a few people asked him in the session, did you speak to him afterwards or?	
Kate	I spoke to Maurice afterwards, but I think most of my questions were answered when, is it Luca?	Comments about questions
Interviewer	Yeah	
Kate	Was talking, but the question about – oh that's how the volcanic bombs, that's the, someone asking a question,	Comments about questions

	that's how that came up, erm and he did talk about his colleagues and how he went out over there, and I thought it was good about how they couldn't camp there because of the risks. That will be good to tell my class when I go back. And the only thing I was going to ask was answered at the end of the talk, it was about flying, and volcanic ash, and how in Sicily it's not a global news at all, but because of Iceland it got London didn't it, and everyone knew about the Icelandic ash cloud, and that happens in Sicily that's not reported on BBC news	
Interviewer	What would you, if he just came now, what would you want to talk about a bit more, or ask him about?	
Kate	Erm	
Bob	I have a silly question in my head, and that's why don't volcanoes float. If they're all made of pumice right? Just like, that's just silly?! [laughs]	Questions: science information
Interviewer	You can ask him that, no question's silly	
Kate	Erm, I suppose it would be a case of obviously there's Etna and he was saying how, where Italy is, because of the African plate and the European plate, and he talked about Stromboli, and he talked about Etna, but I suppose it would be looking at the lines, looking at the other ones. Also the ring of fire, I think I would ask more about that as well, because that was briefly mentioned	Questions: science information
Interviewer	Yeah he said it was called, something was called the ring of fire didn't he	
Bob	Was that to do with the part of the volcano, or was it to do with tectonics?	Questions: science information
Kate	So I'd probably want to ask him a bit more about that I think.	Other and future

	I might research that myself, I might have a look on the internet and have a quick look	engagement: follow-up research
Interviewer	And what, how would you describe him, as a person, a presenter, a scientist?	
Kate	Very approachable I think, I liked the fact that it wasn't all very straight laced, he made it fun.	Descriptions of scientists: post-session
	And he was talking about the guy who will take you up here, and if you go up on a day – we went to Italy in the summer didn't we, we went to Rome and we went to Florence, and stuff and	Making links: personal links to places
	I think if I go back to Italy I would probably want to go and have a look down there, I think if we go back to Italy again, I would like to maybe research going somewhere near there.	Other and future engagement: follow-up research
	Yeah I thought he was really good at presenting what he does, and I liked the fact that he spoke a bit about how he started here, and how he went from university, and what he'd done before, that was good as well.	Descriptions of scientists: post-session
Bob	It's good to know what his background is	
Interviewer	And is that what you expected of a scientist, you were saying you were hoping he was going to be interesting	
Kate	Yeah I thought it was really good	
Bob	Yeah he didn't get too in-depth, I imagine some scientists would want to go off on a big tangent on the composition of lava. But he kept it very simple. So it's nice to know his background because there's a lot of kids in there as well, quite influenced by that kind of thing, kind of helps if they	Descriptions of scientists: post-session

	want to get into that kind of thing. The path they could take, along what he's done already, possibly	
Kate	I really liked the way he was talking about how he had a feeling when he first saw it, I thought that was really good.	References to the experience/event : Authenticity, unique and exclusive
	Because he was being really open about his experiences and how it made him feel, I thought that was really good as well	Descriptions of scientists: post-session
Bob	Passionate	Descriptions of scientists: post-session
Kate	Yeah you could tell he's really passionate about what he's doing. That came across in his talk	Descriptions of scientists: post-session
Interviewer	Yeah definitely. And you were saying that you've been researching volcanoes from books, do you feel that you got anything different from this session?	
Kate	Definitely. Yeah I think I have. And that's why I want to email the, you know the museum, and just see if we can, you know if we are here on a certain day, and see if we can actually have that talk and bring my class along, that would be good	Continued engagement (intentions to return to NHM)
Interviewer	Yeah that would be really good. And then you can kind of pass it on to them, that's something extra, rather than just from a book	
Bob	More memorable, hearing it from a real scientist	References to the experience/event : Authenticity,

unique and exclusive

Interviewer Yeah. Is there anything else you wanted to say, or –

Bob No I don't think so

Kate Just that I thought it was really good. And I wish it was, public – oh that was it, when we were lining up at the doors to go in, because obviously I've been on the actual website, and I've clicked on 'learning' on the tabs, and I think it might be a good idea to kind of have that more in your face when you, when you click on 'learning', to actually have, because obviously I spoke to Maurice and he said, oh if you email us and obviously we will do everything we can to you know get something for your class, get something together. If that was more on the webpage when you click on it, so that you know that you can email

Interviewer Yeah I suppose you have come across it quite, by chance haven't you, today. Whereas if you hadn't have come down

Kate I didn't know about it, and I have been on the website a few times, researching - you've got the red zone and the green zone and all the different things that you've got here. But it's only because we came here today, and only because I wanted to know where the animal live was [another learning programme], that the talk was happening. So I think maybe on the main webpage, if there was a section on the main webpage – did you know there's a talk every day. Maybe I've just missed it, I don't know, it might be good to have something on the main page or on the learning page. To really tell people that it's here.

Interviewer Yeah that's something I get from a lot of people as well, you haven't just missed it, it's not just you

Bob	I think if there's any, any – I mean we went to the red zone, and it was all about volcanoes, and I didn't see any posters saying it was on today
Kate	Posters, no. I think an idea might be to if the scientist's work is to do with the red zone, then put posters up that day to say – if you're interested in this then there's a talk by this scientist, or if their research is to do with something in the green zone have posters that day saying, this is going to be on, come and see it.
Interviewer	Yeah, I guess if people are going to be there they will be interested in it. And it is quite, the other end of the museum as well, so you could quite easily miss it if you don't have time couldn't you
Bob	It's only because we came to the exploration of the cocoon that we
Kate	Have a look at the cocoon. Yeah I'm really glad I came today
Interviewer	Cool

[End of post-session interview recording 7/1/12]

[Start of delayed post-session interview recording (Bob) 7/3/12]

Interviewer	OK so what can you remember about your trip to the museum, and in particular the session where you met the scientist?
Bob	Well yeah, that leaves the most vivid memory, is meeting the, you know having that little show that they did for us. Erm, the most memorable thing, seeing the samples being picked up by the kids, like they were in comparison with normal rocks which you would consider heavy blocks. Yeah just really the demonstrations really, they were my most vivid memory.

Interviewer	Yeah, and can you remember what you found most interesting? About the session?	
Bob	[pause] The session itself? That's a good point, I can't recall [pause]	
Interviewer	That's ok, can you remember what the scientist was like, that you met?	
Bob	Yeah he was very nice yeah. Really sort of easy going, not too sort of formal, it was quite informal, nice sort of expect on the weekend. Actually the most memorable thing actually was when he was talking about the specific volcano he was looking at.	Description of scientist: delayed post-session
	And the part where he mentioned about the volcano, that was next to the one he was studying, it had eroded just down to a little stump, that was about the most interesting part I found.	Specific learning
Interviewer	Yeah, and have you kind of thought about the trip since, or spoken about it with anyone?	
Bob	Yeah I have spoken to people, I've spoken to a couple of guys at work about it. Erm, yeah people with kids I thought would enjoy the demonstration	Other and future engagement: everyday engagement
Interviewer	And have you sort of followed it up in any way, did you go back and look up anything or –	
Bob	I haven't yet no, I do sort of want to when I get some spare 5 minutes, just to sort of look up the Natural History Museum website, and everything and see what's on there. But I haven't as yet, no	Other and future engagement: follow-up research
Interviewer	No, and have you thought of any more questions you would	

	like to ask the scientist, or any more you would want, you may want to hear him talk about	
Bob	Erm, no I don't have any questions you know in the back of my mind. No	
Interviewer	And things kind of things you would want to hear a bit more about from him, or him talk about again?	
Bob	Well if there was a, a another session on you know similar, a follow up kind of thing to explain a bit further what had been doing, because obviously you can't squeeze everything in however long, half an hour, erm, but yeah if there was like a part two if people were interested, I wouldn't mind going to see that. Possibly asking a question about whether he was planning on sort of doing a follow up, a part two if you like	Questions: personal
Interviewer	Yeah, sort of another study or another session?	
Bob	Yeah well I mean, I got the impression that he had done a lot of work on studying the volcano, and possibly couldn't fit everything into the session he had.	Descriptions of scientist: delayed post-session
	So you know just a bit more detail from him. Bit more in depth maybe, for people who aren't too naïve on volcanoes and geology and whatever	Reference to the experience/event : accessibility of information
Interviewer	Yeah, and what do you feel that you got out of the session?	
Bob	[pause] I didn't even know that volcano existed. So I learned a new volcano if you like. And sort of his description of what it's like up close. That's quite useful to have that image in my mind, when you sort of see volcanoes on the telly and whatever. Certainly got the feeling from him that it was quite an imposing thing, to kind of, yeah	Making links – connections to subject
Interviewer	Yeah, and do you think it made you think or feel any	

	differently about anything?	
Bob	Say it again sorry	
Interviewer	Do you think it made you think or feel any differently about anything, the session?	
Bob	Erm, no I think [inaudible]	
Interviewer	And do you have any, sorry what was that?	
Bob	Sorry I'm on a train at the moment	
Interviewer	Oh I didn't realise if it was you or the – and do you have any plans to come back to the museum or see another of the sessions?	
Bob	Erm, not made any plans to come back, but I'd certainly be interested in coming back, and if there's a similar sessions on, advertised on the website or whatever, it would be interesting to come back yeah	Continued engagement (intentions to return to NHM)
Interviewer	Yeah, brilliant. And yeah they are listed on the website so you should be able to find those and find the ones you are interested in.	

[Talk about pseudonym and thanks]

[End of delayed post-session interview recording (Bob) 7/3/12]

[Start of delayed post-session interview recording (Kate) 8/3/12]

Interviewer	OK so what can you remember about your trip to the museum, and in particular the session where you met one of our scientists?	
Kate	OK well obviously I went to the erm talk by the erm volcanologist erm, it was about Stromboli in particular, and his visit and we had some video clips of it.	Descriptions of scientist: delayed post-session

	And then there was little Stromboli as well, the volcano. And it erupts around every 20 minutes, obviously it depends what volcano, obviously every volcano is different. And he spoke to us about Stromboli in particular, and used a demonstration with a stick to explain what was going on.	Specific learning
	Erm, and it was just a, you know he gave us lots of information, and he spoke about the volcanic bombs that you can get. Oh god what else did he say – oh it's hard to, erm, yeah that's probably about as much as I can retain and recall	Descriptions of scientist: delayed post-session
Interviewer	Yeah, that's loads, that's brilliant. And so can you remember what you found most interesting about it?	
Kate	Erm, I think for me it was, the most interesting thing was him and his experience there. And his experience is actually, you know he said he had a moment, it is so amazing to be there. And I think he was saying how kind of, how he was just one person, and how amazing the whole volcano is. That's the most interesting thing that I can remember	Making links: personal links to life experiences and interests
Interviewer	And what can you remember about what he was like?	
Kate	The actual, the volcanologist	
Interviewer	Yeah	
Kate	Very excited, very you know, he was very interested in his own work, and his passion, he was very passionate about it, and that definitely came through. And I think it was just he was a very good speaker as well I think.	Descriptions of scientist: delayed post-session
Interviewer	And have you kind of thought much about the trip since, or spoken about it with anyone else?	
Kate	Yes, I I've spoken to my class about it, because obviously	Other and future

	being a school teacher, erm I can tell them about it.	engagement: everyday engagement
	And I actually took my class there, a couple of weeks ago. And we were in the Attenborough, is it Attenborough studio?	Continued engagement (returned to NHM)
Interviewer	Yeah that's right	
Kate	Yeah and we were there for the Animal Vision talk, which was just as good. And you know my class loved it, and the parents thought it was good as well to help. So yeah, it was really really good. And I've been telling everyone at school you know, I definitely definitely will go back and will take next year when I have to do school trips, we definitely will see what fits with my topics and going back there. To the Natural History Museum, yeah.	Continued engagement (intentions to return to NHM)
	And yeah we've been doing lots of work, we've designed some new logos for the Natural History Museum, and we've been designing carrier bags, because that's one of my design and technology units. Erm, so yeah the class had a really good time, and I'm really glad that I was there on that day and found out about the talk.	Other and future engagement: follow-up research
Interviewer	Yeah, and you've been able to use that quite directly since then.	
Kate	Yep	
Interviewer	Brilliant. And have you, have you yourself followed it up in anyway. Did you look up any more about Stromboli, or?	
Kate	Yes. And I've used that in my school work when I've had to do my volcano topics yeah.	Other and future engagement:

		follow-up research
Interviewer	OK brilliant, and have you thought of any questions or anything else you would like to hear more from, from the scientists, any questions you'd like to ask him, or?	
Kate	Erm, hmm, oh well oh the other thing I forgot to say, it's flooding back now, is um, the pumice stone that he passed that round and stuff, erm, well that kind of thing that was really good as well, and I actually used that with my class, about floating and sinking and how blocks or rocks will sink and that was a good science lesson that I did.	Other and future engagement: follow-up research
	But probably, if I did have a question for him, it would be though, more to do with school, and you know, maybe when I do the topic again, I would want to book a day when he was there, so that he could do the talk with my class, if that makes sense. So yeah that's it I think.	Continued engagement (intentions to return to NHM)
Interviewer	Yeah, so you'd ask him to come and speak to your class or see your class. Brilliant. And what do you feel that you got out of it?	
Kate	I think just, you know how exciting and interesting the whole, looking at the, well his area is obviously a lot higher than my, my level, you know with what I'm doing.	Positioning self in relation to others
	But still the enthusiasm is the same , and I think it was just, getting excited about it, and that really came through from his talk. And I was able to then you know kind of put that enthusiasm into my class, and yeah had a really good topic with it, really good work .	Making links: personal links to job/study
Interviewer	Yeah. And do you think it made you think or feel any differently about anything?	

Kate	Oh definitely. Erm because I've never taught the topic before. And obviously you get lots of information, information books but they can be quite, well not boring but – actually having someone there	Reference to the experience/event : compared to other experiences
	who is obviously very passionate about it , and that's his work, that's his career,	Descriptions of scientists: delayed post-session
	that's yeah, definitely made me feel differently about the whole topic of volcanoes, how interesting they are, how different each volcano is, so yeah	Sparking a new interest
Interviewer	Yeah so you definitely have plans to return to the museum hopefully with your class, do you have any plans just yourself to see any more talks?	
Kate	Erm, I would have to see, holidays or come in the holidays, but if they had a fantastic talk on that had something to do with what I was doing in school, then I would definitely make the trip up to London to go and see the talk	Continued engagement (intentions to return to NHM)
Interviewer	Yeah, yeah brilliant. And then next year hopefully you'll be planning some trips with your class did you say?	
Kate	Yeah	
Interviewer	Brilliant, and finally, unless did you have anything more you wanted to add to that? Or what you?	
Kate	Erm, well just you know that I think the museum is doing a really good job by, my class were really, they absolutely loved their day there, the parents thought it was fantastic. There had obviously been a lot of investment in the museum, and I did want to say actually, I did think about	

that, how helpful every single member of staff, because obviously they are quite easily identifiable, because obviously I had a whole class with me, in a very big museum, and you do kind of think, oh I've got to get to the orange zone to the red zone and then I've got to find the lunch area, every person who I stopped to say, oh I am going the right way aren't I they were so helpful. It was just so good, because I've been to other museums where the staff aren't, that is definitely something that, and obviously as a teacher with a whole class, it was really really good to have, because they were approachable, they were you know everywhere you kind of looked in every area there was someone. Which was really really good because it is such a big museum it could be quite easy to get lost if you know if you don't know where you are going and stuff, so that was really good But, I'll definitely go back to the Natural History Museum, I thought it was a really good experience

Continued engagement (intentions to return to NHM)

[Talk about pseudonyms and thanks]

[End of delayed post-session interview recording 8/3/12]

Appendix V

Example of coded field-notes

Nature Live session: Luca, Researcher (Mineralogy) (2.30pm)

Host: Maurice

Field notes (coded sections highlighted)	Codes
As the audience enter there is a video playing on the screens of a volcanic eruption, and molten larva flowing. Maurice welcomes the audience to the Nature Live, and explains that the NHM is a centre for scientific research and collections, behind the public galleries. Maurice introduces Luca, and they joke about Maurice's pronunciation of Luca's surname. Maurice asks Luca to start by telling the audience what he does at the museum. Maurice and Luca have quite a relaxed and jokey relationship on stage, which makes it funny for the audience. Luca talks with passion and feeling about the volcano he has worked on, and speaks with a strong Italian accent, but clearly and reasonably slowly so that the audience can follow.	Normality: comedy
Luca tells the audience how he started in the museum as a volunteer, classifying meteorites, using an electronic microscope, he was then a curator looking after the rock and mineral collection, and now he is a researcher. He says his current research project sounds crazy, but he is trying to extract energy from volcanic rock to power phone and laptop batteries amongst other things.	Expertise: General
Maurice returns to the fact Luca had said that he was a curator, and talks about the massive collections behind the	

closed doors in the museum, which some people may not realise is there, describing it a bit like a library. Luca agrees, saying that the collections are open for anyone who wants to study or see them, saying that sometimes researchers exchange parts of the collections for a short time to study, for PhD purposes for example.

Maurice moves the conversation on to Stromboli, saying that it is of particular importance to Luca. Luca talks about when he first when to Stromboli, he was sent there to do some work with the visitor education centre on the island, during his PhD research.

Expertise: Education

He says that it was during this work that he first experienced a volcanic eruption, and it made him feel very small, it was an extremely powerful and touching experience, and he gained a greater appreciation of nature and the world around him as a result, he became quite philosophical, and described it as a moment where feelings meet nature.

Normality: vulnerability

Maurice jokes that Luca had told him before, that he had had one too many glasses of red wine this evening, and it was all a bit much. Luca goes on to say that he and his colleagues had been climbing and deserved a rest, so while they were sat watching this ‘spectacle of nature’ they had a glass of wine, and it was a really great experience, Luca said that he’d recommend everyone to see it.

Normality: comedy

Moving on from this, Maurice asks Luca to give a bit of an introduction to what volcanoes are. Luca talks about the structure of the Earth, and what happens when the rigid crust of the Earth collides, forming mountains, or volcanoes. Luca shows on a map that Italy is situated in a region where two tectonic plates collide, creating mountain ranges. He then does a demonstration, using a wooden kebab stick, to show that when pressure builds in the rigid crust, eventually it breaks, and releases energy, forming an earthquake and then a volcano. Prompted by Maurice, Luca then talks about the two different kinds of eruption seen at Stromboli, the ordinary one – every 20-25 minutes, and more powerful ones – every 25 years. Maurice shows a video of the large eruption first, mentioning that they had to mute the sound because there is an Italian geologist swearing in the background. Luca says that the geologists had not expected such a large eruption, so they were a bit scared. He explains about the volatiles, the gases which cause eruptions.

Maurice then puts on a video of the smaller eruption, as Luca explains what happens during this regular, ordinary eruption, with the volatiles and pressure within the volcano. Luca reminds the audience that 'this is the place that left that mark, in me', referring to the first time he saw an eruption. Maurice asks what volatiles are, and Luca explains that these are water, carbon dioxide, and other gases. They also explain that it is this regular eruption which gives Stromboli the nickname 'the Lighthouse of the Mediterranean'.	Normality: other life aspects
Maurice asks if anyone has any questions (10mins 8secs).	
• What's controlling this every 20 minute eruption, why every 20 minutes, who determines, how's it determined? (10mins 12secs)	Questions: science information
Luca explains that it is due to the ratio of the magma rising, releasing the volatiles which cause the eruption, which is controlled by the density and chemical composition of the magma, and linked to the tectonics.	
Maurice puts up a picture of a smaller island which is next to Stromboli, asking Luca to pronounce the Italian name for him. Luca explains that the island is called Strombolicchio, meaning little Stromboli. He says that there is a nice story about this island, if you go to Sicily there are many fishermen who will	Normality: other life aspects

take you out to see it, and give you dinner and a nice glass of wine, and then they will tell you that Strombolicchio is the cork of Stromboli which flew off in an eruption, eventually landing next to it. Luca says that it's a nice story, but unfortunately is not true.

Strombolicchio is in fact a previous volcanic neck, another eruptive point before Stromboli itself, which has now eroded away. Luca also talks about how Stromboli is actually much larger than it looks, as much of it is under the sea, we only see the tip.

Expertise: general

- Does it ever spit out like large bits of rock that might be dangerous to boats? (13mins 26secs)

Questions: science information

Luca says that yes, during an eruption the volcano might spit out what is called 'volcanic bombs', rock which is ejected very quickly cools very quickly, and hardens. The danger is there, although the crater is very deep. Luca says that if you go there you can be taken to the summit by a guide, which is 100m above the crater so you can see inside it.

Maurice asks about the location of Stromboli, and nearby volcanoes. Luca mentions Etna and the differences in chemistry between the magma of Etna and Stromboli and the larva and rocks which are created as a result. Luca asks for a small volunteer to help him lift the rock, eventually revealing that it is very light. Maurice jokes that Luca has been planning that joke for months. The audience laugh. The piece of pumice is then passed around the audience, as Luca talks about how it is formed during an eruption, and demonstrates that the rock floats because it has lots of holes which contain air. People look at the pumice with interest, many pause to look at it for a few seconds.

Normality: comedy

The conversation then moves on to talking about the dangers of Stromboli, and whether we should be worried about it. Luca talks about the structure of the volcano, and one flank which is unstable and has collapsed many times. Some of these collapses are minor, there hasn't been a large collapse in thousands of years, but these little collapses or landslides still cause tsunamis by moving a body of water quickly. They show a video of one collapse, which causes a large wave.

- How long would you expect it to carry on erupting so regularly, and when, will it start erupting less regularly? (20mins 37secs)

Questions: science information

Luca says that this depends on how the plates move, but this would be over millions of years – so they don't really know. Maurice says that there was another question from another member of the audience, but he says that it was very similar to the previous question.

Maurice says that there was one last thing he wanted Luca to talk about, and that is volcanic ash, putting up a picture of ash particles under a microscope. Luca talks about how he worked on ash for his thesis, and this picture was one he had taken to show the structure of the ash particles. He speaks also about Etna, and how there is an airport nearby called the Red Fountain airport, which, he says, says it all. When Etna erupts the airport closes down, but hardly anyone knows, apart from Luca who can't get home. Whereas if there is a volcanic eruption in Iceland, and the ash blows to London, it is on breaking news, everyone knows about it, and everyone asks why this hasn't happened before. Luca says that is does happen very often, but it is only him who knows about it, and others in Sicily trying to get home.

Expertise: education

Normality: other life aspects

Maurice concludes by talking about other Nature Live events which happen in the museum, saying that all the Museum scientists are lovely like Luca, and that the audience should come back if they want to meet any more of the other Museum scientists and ask them questions.

Event brief from website:

Stomboli: Lighthouse of the Mediterranean

The volcano on the island of Stromboli has a very bizarre personality: it erupts every 20 minutes. This has earned it the nickname 'the lighthouse of the Mediterranean'. Join us as we find out more about this volcano, why it is different to the others in Italy and the potential dangers it poses to the locals.